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(21) International Application Number: PCT/US92/08999 (22) International Filing Date: 23 October 1992 (23.10.92) (30) Priority data: 781,356 25 October 1991 (25.10.91) US 863,641 3 April 1992 (03.04.92) US (71) Applicant: SAN DIEGO REGIONAL CANCER CENTER [US/US]; 3099 Science Park Road, Suite 200, San Diego, CA 92121 (US). (72) Inventors: SOBOL, Robert, E. ; 5673 La Jolla Hermosa Avenue, La Jolla, CA 92037 (US). FRED, H., Gage ; 8388 Caminito Helecho, La Jolla, CA 92037 (US). ROYSTON, Ivor ; 1515 El Camino del Teatro, La Jolla, CA 92037 (US). FRIEDMAN, Theodore ; 9470 La Jolla Shores Drive, La Jolla, CA 92037 (US). FAKHRAI, Habib ; 1538 Avenida Andante, Oceanside, CA 92056 (US).		(74) Agents: CAMPBELL, Cathryn et al.; Campbell & Flores, 4370 La Jolla Village Drive, Suite 700, San Diego, CA 92122 (US). (81) Designated States: CA, JP, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, SE). Published <i>With international search report.</i>
(54) Title: LYMPHOKINE GENE THERAPY OF CANCER (57) Abstract <p>A novel method of tumor immunotherapy is described comprising the genetic modification of cells resulting in the secretion of cytokine gene products to stimulate a patient's immune response to tumor antigens. In one embodiment, autologous fibroblasts genetically modified to secrete at least one cytokine gene product are utilized to immunize the patient in a formulation with tumor antigens at a site other than an active tumor site. In another embodiment, cells genetically modified to express at least one tumor antigen product and to secrete at least one cytokine gene product are utilized in a formulation to immunize the patient at a site other than an active tumor site.</p>		

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Lymphokine Gene Therapy of CancerBACKGROUND

This application is a continuation-in-part of United States Patent Application Serial No. 07/781,356, filed on October 25, 1991, which is a continuation-in-part of United States Patent Application Serial No. 07/720,872, filed on June 25, 1991, both of which are incorporated herein in their entirety.

Recent advances in our understanding of the biology of the immune system have lead to the identification of important modulators of immune responses, called cytokines (1-3). Immune system modulators produced by lymphocytes are termed lymphokines, a subset of the cytokines. These agents mediate many of the immune responses involved in anti-tumor immunity. Several of these cytokines have been produced by recombinant DNA methodology and evaluated for their anti-tumor effects. The administration of lymphokines and related immunomodulators has resulted in objective tumor responses in patients with various types of neoplasms (4-7). However, current modes of cytokine administration are frequently associated with toxicities that limit the therapeutic value of these agents.

For example, interleukin-2 (IL-2) is an important lymphokine in the generation of anti-tumor immunity (4). In response to tumor antigens, a subset of lymphocytes termed helper T-cells secrete small quantities of IL-2. This IL-2 acts locally at the site of tumor antigen stimulation to activate cytotoxic T-cells and natural killer cells which mediate systemic tumor cell destruction. Intravenous, intralymphatic and intralesional administration of IL-2 has resulted in clinically significant responses in some cancer patients (4-6). However, severe toxicities (hypotension and adema) limit the dose and efficacy of intravenous and intralymphatic IL-

2 administration (5-7). The toxicity of systemically administered lymphokines is not surprising as these agents mediate local cellular interactions and they are normally secreted in only very small quantities.

5 Additionally, other cytokines, such as interleukin-4 (IL-4), alpha interferon (α -INF) and gamma interferon (γ -INF) have been used to stimulate immune responses to tumor cells. Like IL-2, the current modes of administration have adverse side effects.

10 To circumvent the toxicity of systemic cytokine administration, several investigators have examined intralesional injection of IL-2. This approach eliminates the toxicity associated with systemic IL-2 administration (8,9,10). However, multiple intralesional injections are
15 required to optimize therapeutic efficacy (9,10). Hence, these injections are impractical for many patients, particularly when tumor sites are not accessible for injection without potential morbidity.

 An alternative approach, involving cytokine gene
20 transfer into tumor cells, has resulted in significant anti-tumor immune responses in several animal tumor models (11-14). In these studies, the expression of cytokine gene products following cytokine gene transfer into tumor cells has abrogated the tumorigenicity of the cytokine-secreting
25 tumor cells when implanted into syngeneic hosts. The transfer of genes for IL-2 (11,12) γ -INF (13) or interleukin-4 (IL-4) (14) significantly reduced or eliminated the growth of several different histological types of murine tumors. In the studies employing IL-2 gene
30 transfer, the treated animals also developed systemic anti-tumor immunity and were protected against subsequent tumor challenges with the unmodified parental tumor (11,12). Similar inhibition of tumor growth and protective immunity was also demonstrated when immunizations were performed

with a mixture of unmodified parental tumor cells and genetically modified tumor cells engineered to express the IL-2 gene. No toxicity associates with localized lymphokine transgene expression was reported in these
5 animal tumor studies (11-14).

While the above gene-transfer procedure has been shown to provide anti-tumor immunity, it still retains practical difficulties. This approach is limited by the inability to transfer functional cytokine genes into many
10 patients' tumor cells, as most patients' tumors cannot be established to grown in vitro and methods for human in vivo gene transfer are not available.

SUMMARY OF THE INVENTION

The present invention demonstrates a novel, more
15 practical method of cytokine cancer immunotherapy. In one approach, selected cells from a patient, such as fibroblasts, obtained, for example, from a routine skin biopsy, are genetically modified to express one or more cytokines. Alternatively, patient cells which may normally
20 serve as antigen presenting cells in the immune system such as macrophages, monocytes, and lymphocytes may also be genetically modified to express one or more cytokines. These modified cells are hereafter called cytokine-expressing cells, ore CE cells. The CE cells are then
25 mixed with the patient's tumor antigens, for example in the form of irradiated tumor cells, or alternatively in the form of purified natural or recombinant tumor antigen, and employed in immunizations, for example subcutaneously, to induce systemic anti-tumor immunity.

30 The cytokines are locally expressed at levels sufficient to induce or augment systemic anti-tumor immune responses via local immunization at sites other than active tumor sites. Systemic toxicity related to cytokine

administration should not occur because the levels of cytokine secreted by the CE cells should not significantly affect systemic cytokine concentrations.

As the amount of cytokine secreted by the CE
5 cells is sufficient to induce anti-tumor immunity but is too low to produce substantial systemic toxicity, this approach provides the benefit of local cytokine administration. In addition, this novel method obviates the need for intralesional injections, which may produce
10 morbidity. Furthermore, the continuous local expression of cytokine(s) at the sites of immunization may also augment anti-tumor immune responses compared to intermittent cytokine injections. This method also provides the advantage of local immunization with the CE cells, as
15 opposed to cumbersome intravenous infusions. This method also eliminates the need for establishing tumor cell lines in vitro as well as transfer of genes into these tumor cells.

This invention also provides an alternative means
20 of localized expression of cytokines to induce and/or increase immune responses to a patient's tumor through genetic modification of cellular expression of both cytokine(s) and tumor antigen(s). In this embodiment, selected cells from a patient are isolated and transduced
25 with cytokine gene(s) as well as gene(s) coding for tumor antigen(s). The transduced cells are called "carrier cells." Carrier cells can include fibroblasts and cells which may normally serve as antigen presenting cells in the immune system such as macrophages, monocytes, and
30 lymphocytes. Transduced carrier cells actively expressing both the cytokine(s) and the tumor antigen(s) are selected and utilized in local immunizations at a site other than active tumor sites to induce anti-tumor immune responses. As with the CE cells, these carrier cells should not
35 produce substantial systemic toxicities, as the levels of

cytokine(s) secreted by the carrier cells should not significantly affect systemic cytokine concentrations. This alternate embodiment is advantageous because it obviates the need to obtain samples of the tumor, which is sometimes difficult. However, carrier cells can be utilized in local immunizations in conjunction with tumor cells, tumor cell homogenates, purified tumor antigens, or recombinant tumor antigens to enhance anti-tumor immunity.

Additionally, this second embodiment retains the same advantages as the first embodiment in that the level of cytokine released by the carrier cells is sufficient to induce anti-tumor immunity but is too low to produce substantial systemic toxicity. In addition, as with the first embodiment, this method obviates the need for intralesional injections, and allows for continuous expression of cytokine(s). This method also eliminates the need for establishing continuous cultures in vitro of tumor cells as well as transfer of genes into these tumor cells, and provides the advantage of local immunization with the carrier cells, as opposed to cumbersome lengthy intravenous infusions.

These approaches may also find application in inducing or augmenting immune responses to other antigens of clinical significance in other areas of medical practice.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows schematic diagrams of retroviral vectors DC/TKIL2, LXSIL-IL2, and LNCX-IL2.

Figure 2 shows a mean IL-2 concentration of triplicate supernatant samples measured by ELISA. Supernatants were harvested from overnight cultures of approximately 1.5×10^6 semi-confluent fibroblasts.

Figure 3 shows biological activity of the IL-2 secreted by the transduced fibroblasts was demonstrated by measuring mean ^3H -TdR incorporation of an IL-2 dependent T-cell line incubated with triplicate samples of supernatants. Supernatants were harvested from overnight cultures of approximately 1.5×10^6 semi-confluent fibroblasts.

Figure 4 shows comparisons between animals injected with 10^5 CT26 tumor cells alone (\square); 10^5 CT26 tumor cells and 2×10^6 unmodified BALB/C fibroblasts (\blacksquare); 10^5 CT26 tumor cells and 2×10^6 IL-2 transduced BALB/C fibroblasts (\bullet); and 10^5 CT26 tumor cells and 1×10^6 transduced BALB/C fibroblasts (\circ). Tumor measurements are the mean products of the cross-sectional diameter of the tumors from four animals in each treatment group. The (*) indicates statistically significant difference ($P < 0.05$) in tumor growth curves.

Figure 5 shows PCR analysis of neomycin phosphotransferase DNA sequences. Lane 1 - positive control pLXSN-RI-IL2. Lanes 2 through 4 tests genomic DNA; Lanes 5 and 6 ovary genomic DNA; Lane 7 negative control, no DNA. Identical results were obtained with liver, spleen and lung genomic DNA (data not shown).

Figure 6 shows the effect of IL-2 modified fibroblasts on tumor establishment and development using 2×10^6 fibroblasts mixed with 5×10^4 CT26 tumor cells concentrating on the rate of tumor growth.

Figure 7 shows the effect of IL-2 modified fibroblasts on tumor establishment and development using 2×10^6 fibroblasts mixed with 5×10^4 CT26 tumor cells concentrating on the time of tumor onset for the individual animal in each treatment group.

Figure 8 shows the effect of IL-2 modified fibroblasts on tumor establishment and development using 2×10^6 fibroblasts mixed with 1×10^5 CT26 tumor cells concentrating on the rate of tumor growth.

5 Figure 9 shows the effect of IL-2 modified fibroblasts on tumor establishment and development using 2×10^6 fibroblasts mixed with 1×10^5 CT26 tumor cells concentrating on the time of tumor onset for the individual animal in each treatment group.

10 Figure 10 shows the effect of IL-2 modified cells on tumor establishment and development using 2×10^6 DCTK-IL2-modified CT26 tumor cells mixed with 1×10^5 unmodified CT26 compared to 2×10^6 DCTK-IL2-modified fibroblasts mixed with 1×10^5 CT26 concentrating on the rate of tumor growth.

15 Figure 11 shows the effect of IL-2 modified cells on tumor establishment and development using 2×10^6 DCTK-IL2-modified CT26 tumor cells mixed with 1×10^5 unmodified CT26 compared to 2×10^6 DCTK-IL2-modified fibroblasts mixed with 1×10^5 CT26 concentrating on the time of tumor onset
20 for the individual animal in each treatment group.

Figure 12 shows the effect of IL-2 modified fibroblasts on induction of systemic anti-tumor immunity and the rate of tumor growth. Mice were immunized with 2×10^6 fibroblasts mixed with 2.5×10^5 irradiated CT26 tumor
25 cells 7 days prior to challenge with 5×10^4 fresh tumor cells.

Figure 13 shows the effect of IL-2 modified fibroblasts on induction of systemic anti-tumor immunity and the time of tumor onset for the individual animal in
30 each treatment group. Mice were immunized with 2×10^6 fibroblasts mixed with 2.5×10^5 irradiated CT26 tumor cells 7 days prior to challenge with 5×10^4 fresh tumor cells.

Figure 14 shows the effect of IL-2 modified fibroblasts on induction of systemic anti-tumor immunity and the rate of tumor growth. Mice were immunized with 2×10^6 fibroblasts mixed with 2.5×10^5 irradiated CT26 tumor cells 14 days prior to challenge with 5×10^4 fresh tumor cells.

Figure 15 shows the effect of IL-2 modified fibroblasts on induction of systemic anti-tumor immunity and the time of tumor onset for the individual animal in each treatment group. Mice were immunized with 2×10^6 fibroblasts mixed with 2.5×10^5 irradiated CT26 tumor cells 14 days prior to challenge with 5×10^4 fresh tumor cells.

DETAILED DESCRIPTION

A novel method of tumor immunotherapy is described comprising the genetic modification of cells resulting in the secretion of cytokine gene products to stimulate a patient's immune response to tumor antigens. "Gene" is defined herein to be a nucleotide sequence encoding the desired protein. In one embodiment, autologous fibroblasts genetically modified to secrete at least one cytokine gene product are utilized to immunize the patient in a formulation with tumor antigens at a site other than an active tumor site. In another embodiment, cells genetically modified to express at least one tumor antigen gene product and to secrete at least one cytokine gene product are utilized in formulation to immunize the patient at a site other than an active tumor site. Cytokines are preferably expressed in cells which efficiently secrete these proteins into the surrounding milieu. fibroblasts are an example of such cells. Fibroblasts or other cells can be genetically modified to express and secrete one or more cytokines, as described later in this specification.

Tumor antigens can be provided by several methods, including, but not limited to the following: 1) CE cells can be transduced with gene(s) coding for tumor antigens. These "carrier cells" are then utilized in patient immunizations. 2) Cloned gene sequences coding for appropriate tumor antigens can be transferred into cells such as fibroblasts or antigen-presenting cells. These cells are then mixed with CE or carrier cells to immunize the patient. 3) Tumor antigens can be cloned in bacteria or other types of cells by recombinant procedures. These antigens are then purified and employed in an immunization with CE and/or carrier cells. 4) Tumor antigens can be purified from tumor cells and used, along with CE or carrier cells, to immunize the patient. 5) Tumor cells may be irradiated or mechanically disrupted and mixed with CE and/or carrier cells for patient immunizations.

This invention encompasses the following steps: (A) isolation of appropriate cells for generation of CE cells or carrier cells; (B) isolation of cytokine genes or isolation of cytokine genes and tumor antigen genes, as well as appropriate marker and/or suicide genes; (C) transfer of the genes from (B) to produce the CE cells or carrier cells; (D) preparation of immunological samples of the patient's tumor antigens or other suitable tumor antigens for immunization with CE or carrier cells; (E) inactivation of the malignant potential of tumor cells if they are used as a source of tumor antigens for immunization; and (F) preparation of samples for immunization. Following are several embodiments contemplated by the inventors. However, it is understood that any means known by those in the art to accomplish these steps will be usable in this invention.

(A) Isolation of Cells to Generate CE and Carrier Cells

Cells to be utilized as CE cells and carrier cells can be selected from a variety of locations in the patient's body. For example, skin punch biopsies provide a readily available source of fibroblasts for use in generating CE cells, with a minimal amount of intrusion to the patient. alternatively, these fibroblasts can be obtained from the tumor sample itself. Cells of hematopoietic origin may be obtained by venipuncture, bone marrow aspiration, lymph node biopsies, or from tumor samples. Other appropriate cells for the generation of CE or carrier cells can be isolated by means known in the art. Non-autologous cells similarly selected and processed can also be used.

(B) Isolation of Genes

Numerous cytokine genes have been cloned and are available for use in this protocol. The genes for IL-2, γ -INF and other cytokines are readily available (1-5, 11-14). Cloned genes of the appropriate tumor antigens are isolated according to means known in the art.

Selectable marker genes such as neomycin resistance (Neo^R) are readily available. Incorporation of a selectable marker gene(s) allows for the selection of cells that have successfully received and express the desired genes. Other selectable markers known to those in the art of gene transfer may also be utilized to generate CE cells or carrier cells expressing the desired transgenes.

"Suicide" genes can be incorporated into the CE cells or carrier cells to allow for selective inducible killing after stimulation of the immune response. A gene

such as the herpes simplex virus thymidine kinase gene (TK) can be used to create an inducible destruction of the CE cells or carrier cells. When the CE cells or carrier cells are no longer useful, a drug such as acyclovir or gancyclovir can be administered. Either of these drugs will selectively kill cells expressing TK, thus eliminating the implanted transduced cells. Additionally, a suicide gene may be a gene coding for a non-secreted cytotoxic polypeptide attached to an inducible promoter. When destruction of the CE or carrier cells is desired, the appropriate inducer of the promoter is administered so that the suicide gene is induced to produce cytotoxic polypeptide which subsequently kills the CE or carrier cell. However, destruction of the CE or carrier cells may not be required.

Genes coding for tumor antigen(s) of interest can be cloned by recombinant methods. The coding sequence of an antigen expressed by multiple tumors may be utilized for many individual patients.

20 (C) Transfer of Genes

Numerous methods are available for transferring genes into cultured cells (15). For example, the appropriate genes can be inserted into vectors such as plasmids or retroviruses and transferred into the cells. Electroporation, lipofection and a variety of other methods are known in the field and can be implemented.

One method for gene transfer is a method similar to that employed in previous human gene transfer studies, where tumor infiltrating lymphocytes (TILs) were modified by retroviral gene transduction and administered to cancer patients (16). In this Phase I safety study of retroviral mediated gene transfer, TILs were genetically modified to express the Neomycin resistance (Neo^R) gene. Following

intravenous infusion, polymerase chain reaction analyses consistently found genetically modified cells in the circulation for as long as two months after administration. No infectious retroviruses were identified in these
5 patients and no side effects due to gene transfer were noted in any patients (16). These retroviral vectors have been altered to prevent viral replication by the deletion of viral gag, pol and env genes.

When retroviruses are used for gene transfer,
10 replication competent retroviruses may theoretically develop by recombination between the retroviral vector and viral gene sequences in the packaging cell line utilized to produce the retroviral vector. We will use packaging cell lines in which the production of replication competent
15 virus by recombination has been reduced or eliminated. Hence, all retroviral vector supernatants used to infect patient cells will be screened for replication competent virus by standard assays such as PCR and reverse transcriptase assays (16). Furthermore, exposure to
20 replication competent virus may not be harmful. In studies of subhuman primates injected with a large inoculum of replication competent murine retrovirus, the retrovirus was cleared by the primate immune system (17). No clinical illnesses or sequelae resulting from replication competent
25 virus have been observed three years after exposure. In summary, it is not expected that patients will be exposed to replication competent murine retrovirus and it appears that such exposure may not be deleterious (17).

30 (D) Preparation of Immunological Samples of the Patient's Tumor Antigens or Purified Recombinant Tumor Antigens

Tumor cells bearing tumor associated antigens are isolated from the patient. These cells can derive either from solid tumors or from leukemic tumors. For solid

tumors, single-cell suspensions can be made by mechanical separation and washing of biopsy tissue (18).

Hematopoietic tumors may be isolated from peripheral blood or bone marrow by standard methods (19).

5 A second variant is the use of homogenates of tumor cells. Such homogenates would contain tumor antigens available for recognition by the patient's immune system upon stimulation by this invention. Either unfractionated cell homogenates, made, for example, by mechanical
10 disruption or by freezing and thawing the cells, or fractions of homogenates preferably with concentrated levels of tumor antigens, can be used.

 Likewise, purified tumor antigens, obtained for example by immunoprecipitation or recombinant DNA methods,
15 could be used. Purified antigens would then be utilized for immunizations together with the CE cells and/or carrier cells described above to induce or enhance the patient's immune response to these antigens.

 In the embodiments employing carrier cells, tumor
20 antigens are available through their expression by the carrier cells. These carrier cells can be injected alone or in conjunction with other tumor antigen preparations or CE cells. Likewise, when CE cells are used, purified recombinant tumor antigen, produced by methods known in the
25 art, can be used.

 If autologous tumor cells are not readily available, heterologous tumor cells, their homogenates, their purified antigens, or carrier cells expressing such antigens could be used.

(E) Inactivation of Tumor Cells

When viable tumor cells are utilized in immunizations as a source of tumor antigens, the tumor cells can be inactivated so that they do not grow in the patient. Inactivation can be accomplished by several methods. the cells can be irradiated prior to immunization (18). This irradiation will be at a level which will prevent their replication. Such viable calls can then present their tumor antigens to the patient's immune system, but cannot multiply to create new tumors.

Alternatively, tumor cells that can be cultured may be transduced with a suicide gene. As described above, a gene such as the herpes simplex thymidine kinase (TK) gene can be transferred into tumor cells to induce their destruction by administration of acyclovir or gancyclovir. After immunization, the TK expressing tumor cells can present their tumor antigens, and are capable of proliferation. After a period of time during which the patients's immune response is stimulated, the cells can be selectively killed. This approach might allow longer viability of the tumor cells utilized for immunizations, which may be advantageous in the induction or augmentation of anti-tumor immunity.

(F) Preparation of Samples for Immunization

CE cells and/or carrier cells and tumor cells, and/or homogenates of tumor cells and/or purified tumor antigen(s), are combined for patient immunization. Approximately 10^7 tumor cells will be required. If homogenates of tumor cells or purified or non-purified fractions of tumor antigens are used, the tumor dose can be adjusted based on the normal number of tumor antigens usually present on 10^7 intact tumor cells. The tumor preparation should be mixed with numbers of CE or carrier

cells sufficient to secrete cytokine levels that induce anti-tumor immunity (11-12) without producing substantial systemic toxicity which would interfere with therapy.

The cytokines should be produced by the CE cells or the carrier cells at levels sufficient to induce or augment immune response but low enough to avoid substantial systemic toxicity. This prevents side effects created by previous methods' administration of greater than physiological levels of the cytokines.

10 These mixtures, as well as carrier cells that are utilized alone, will be formulated for injection in any manner known in the art acceptable for immunization. Because it is important that at least the CE cells and carrier cells remain viable, the formulations must be
15 compatible with cell survival. Formulations can be injected subcutaneously, intramuscularly, or in any manner acceptable for immunization.

 Contaminants in the preparation which may focus the immune response on undesired antigens should be removed
20 prior to the immunizations.

 The following examples are provided for illustration of several embodiments of the invention and should not be interpreted as limiting the scope of the invention.

EXAMPLE IIMMUNIZATION WITH FIBROBLASTS EXPRESSING IL-2
MIXED WITH IRRADIATED TUMOR CELLS5 1) Isolation of Autologous Fibroblasts
for Use in Generating IL-2 Secreting CE Cells

Skin punch biopsies will be obtained from each patient under sterile conditions. The biopsy tissue will be minced and placed in RPMI 1640 media containing 10% fetal calf serum (or similar media) to establish growth of the skin fibroblasts in culture. The cultured fibroblasts will be utilized to generate IL-2 secreting CE cells by retroviral mediated IL-2 gene transfer.

2) Retroviral Vector Preparation and
Generation of IL-2 Secreting CE Cells

15 The cultured skin fibroblasts will then be infected with a retroviral vector containing the IL-2 and Neomycin resistance (Neo^R) genes. An N2 vector containing the Neo^R gene will be used, and has been previously utilized by a number of investigators for in vitro and in vivo work, including investigations with human subjects (16). The IL-2 vector will be generated from an N2-derived vector, LLRNL, developed and described by Friedmann and his colleagues (20). It will be made by replacement of the luciferase gene of LLRNL with a full-length cDNA encoding human IL-2. Retroviral vector free of contaminating replication-competent virus is produced by transfection of vector plasmid constructions into the helper-free packaging cell line PA317. Before infection of patients' cells, the vector will have been shown to be free of helper virus. In the event that helper virus is detected, the vector will be produced in the GP + envAM12 packaging cell line in which

the viral gag and pol genes are separated from the env, further reducing the likelihood of helper virus production.

3) Transduction Protocol

The cultured primary fibroblasts will be incubated with supernatant from the packaging cell line as described (20). Supernatant from these cells will be tested for adventitious agents and replication competent virus as described (16) and outlined in Table 1. The fibroblasts are washed and then grown in culture media containing G418, (a neomycin analogue) to select for transduced cells expressing the Neo^R gene. The G418-resistant cells will be tested for expression of the IL-2 gene by measuring the concentration of IL-2 in the culture supernatant by an enzyme linked immunosorbent assay (ELISA) (12). G418-resilient cells expressing IL-2 will be stored at -70°C until required for subsequent use in immunizations.

Table 1

Adventitious Agents and Safety Testing

20	1. Sterility
	2. Mycoplasma
	3. General Safety
	4. Viral Testing
	LCM Virus
25	Thymic agent
	S+/L- eco
	S+/L-xeno
	S+/L- ampho
	3T3 amplification
30	MRC-5/Vero

4) Preparation of Irradiated Tumor Cells

Tumors obtained from clinically indicated surgical resections or from superficial lymph node or skin metastases will be minced into 2-3 mm pieces and treated with collagenase and DNase to facilitate separation of the tumor into a single cell suspension. The collected cells will be centrifuged and washed in RPMI 1640 media and then cryopreserved in a solution containing 10% dimethyl sulphoxide and 50% fetal calf serum in RPMI 1640 media. The cells will be stored in liquid nitrogen until the time of administration. Prior to their use in subcutaneous immunizations, the cells will be thawed, washed in media free of immunogenic contaminants, and irradiated with 4,000 rads per minute for a total of 20,000 rads in a cesium irradiator.

5) Patient Selection

Patients will have a histologically confirmed diagnosis of cancer. Patients with tumors that must be resected for therapeutic purposes or with tumors readily accessible for biopsy are most appropriate for this embodiment of the invention.

6) Pretreatment Evaluation

The following pretreatment evaluations will be performed:

- 1) History and physical examination including a description and quantification of disease activity.

2) Performance Status Assessment

0 = Normal, no symptoms

1 = Restricted, but ambulatory

2 = Up greater than 50% of waking hours, capable of self-care

3 = Greater than 50% of waking hours confined to bed or chair, limited self-care

4 = Bedridden

5

3) Pretreatment Laboratory:

CBC with differential, platelet count, PT, PTT, glucose, BUN, creatinine, electrolytes, SGOT, SGPT, LDH, alkaline phosphatase, bilirubin, uric acid, calcium, total protein albumin.

10

4) Other Analyses:

Urinalysis

CH₅₀, C₃ and C₄ serum complement levels

Immunophenotyping of peripheral blood B cell and T cell subsets

15

Assays for detectable replication-competent virus in peripheral blood cells

PCR assays of peripheral blood leukocytes for Neo^R, IL-2 and viral env

20

5) Other Pretreatment Evaluation:

25

Chest X-ray and other diagnostic studies including computerized tomography (CT), magnetic resonance imaging (MRI) or radionuclide scans may be performed to document and quantify the extent of disease activity.

Follow-up evaluations of these assessments at regular intervals during the course of therapy (approximately every 1 to 3 months) will be useful in determining response to therapy and potential toxicity,

30

permitting adjustments in the number of immunizations administered.

7) Restrictions on Concurrent Therapy

For optimal effects of this treatment, patients
5 should receive no concurrent therapy which is known to suppress the immune system.

8) Final Formulation

Each patient will receive subcutaneous
immunizations with a mixture of irradiated tumor cells and
10 autologous fibroblast CE cells genetically modified to secrete IL-2. Approximately 10^7 tumor cells will be mixed with 10^7 fibroblasts known to secrete at least 20 units/ml of IL-2 in tissue culture when semi-confluent (12). The
irradiated tumor cells and genetically modified fibroblasts
15 will be placed in a final volume of 0.2 ml normal saline for immunization.

9) Dose Adjustments

At least two subcutaneous immunizations will be
administered, two weeks apart, with irradiated tumor cells
20 and autologous fibroblasts genetically modified to secrete IL-2. If no toxicity is observed, subsequent booster immunizations may be administered periodically (at least one week apart) to optimize the anti-tumor immune response.

J) Treatment of Potential Toxicity

25 Toxic side effects are not expected to result from these immunizations. However, potential side effects of these immunizations are treatable in the following manner:

If massive tumor cell lysis results, any resulting uric acid nephropathy, adult respiratory distress syndrome, disseminated intravascular coagulation or hyperkalemia will be treated using standard methods.

- 5 Local toxicity at the sites of immunization will be treated with either topical steroids and/or surgical excision of the injection site as deemed appropriate.

- Hypersensitivity reactions such as chills, fever and/or rash will be treated symptomatically with
10 antipyretics and antihistamines. Patients should not be treated prophylactically. Should arthralgias, lymphadenopathy or renal dysfunction occur, treatment with corticosteroids and/or antihistamines will be instituted. Anaphylaxis will be treated by standard means such as
15 administration of epinephrine, fluids, and steroids.

EXAMPLE II

A. Retroviral IL-2 Gene Transfer and Expression in Fibroblasts

- Retroviral vectors were employed to transfer and
20 express IL-2 and neomycin phosphotransferase genes in murine and primary human fibroblasts. The retroviral vector DC/TKIL2 produced by Gilboa and co-workers (Gansbacher, et al., J. Exp. Med. 172:1217-1223, 1990, which is incorporated herein by reference) was utilized to
25 transduce murine fibroblasts for application in an animal tumor model (see Section B below). Human fibroblasts were transduced with the retroviral vector LXSNI-RI-IL2. Schematic diagrams of the structure of these retroviral vectors are provided in Figure 1. A more complete
30 description of the LXSNI-RI-IL2 vector, including its nucleotide sequence, is provided in Example III and in Tables 2, 3 and 4.

Following infection with the described vectors and selection for 2-3 weeks in growth media containing the neomycin analogue G418, Balb/c and human embryonic fibroblast culture supernatants were harvested and tested
5 for IL-2 by an enzyme-linked immunosorbent assay (ELISA). Figure 2 depicts the levels of IL-2 secreted by the transduced fibroblasts.

These results can be confirmed using negative control fibroblasts infected with an N2-derived retroviral
10 vector expressing an irrelevant gene such as luciferase or β -galactosidase and studies with adult human fibroblasts.

Biological activity of the IL-2 expressed by the transduced human fibroblasts was confirmed by a cell proliferation bioassay employing an IL-2 dependent T cell
15 line. In this assay, supernatant from the transduced fibroblasts and control unmodified fibroblasts were incubated with the IL-2 dependent T cell line CTLL-2. Incorporation of ^3H -thymidine was measured as an indicator of cell proliferation and IL-2 activity (Figure 3).

20 B. Efficacy of Transduced Fibroblasts in an Animal Tumor Model

The efficacy of fibroblasts genetically modified to secrete IL-2 was tested in an animal model of colorectal carcinoma. In these studies, the Balb/c CT26 tumor cell
25 line was injected subcutaneously with Balb/c fibroblasts transduced to express IL-2. Control groups included animals injected with 1) a mixture of CT26 tumor cells and unmodified fibroblasts; 2) CT26 tumor cells without fibroblasts and 3) transduced fibroblasts alone. No tumors
30 were detected in 3/8 animals treated with transduced fibroblasts and CT26 cells. In contrast, all untreated control animals (8/8) injected with CT26 tumor cells developed palpable tumors. No tumors were detected in the

animals inoculated with transduced fibroblasts without CT26 tumor cells. The mean CT26 tumor size in Balb/c mice injected with the IL-2 secreting fibroblasts was considerably smaller compared to the control groups (Figure 4). A multivariate non-parametric statistical procedure (Koziol, et al., Biometrics 37:383-390, 1981 and Koziol, et al., Computer Prog. Biomed. 19:69-74, 1984, which is incorporated herein by reference) was utilized to evaluate differences in tumor growth among the treatment groups. The tumor growth curves for the four treatment groups presented in Figure 4 were significantly different ($p=0.048$). Subsequent comparisons between treatment groups revealed a significant difference ($p < 0.05$) in tumor growth between animals injected with CT26 tumor cells alone and animals treated with 2×10^6 transduced fibroblasts and CT26 tumor cells (Figure 4).

EXAMPLE III

A. Project Overview

Lymphokine gene therapy of cancer will be evaluated in cancer patients who have failed conventional therapy. An N2-derived vector containing the neomycin phosphotransferase gene will be used. This vector has been employed by a number of investigators for in vitro and in vivo studies including recently approved investigations with human subjects (Rosenberg et al., N. Eng. J. Med., 323:570-578, 1990). The lymphokine vectors used in this investigation will be generated from the N2-derived vector, LXS_N, developed and described by Miller et al., Mol. Cell Biol. 6:2895, 1986 and Miller et al., BioTechniques 7:980, 1989, which are incorporated herein by reference. The vector LXS_N-RI-IL2 contains human IL-2 cDNA under the control of the retroviral 5' LTR promoter and the neomycin phosphotransferase gene under the control of the SV40 promoter (see Figure 1). The normal human IL-2 leader

sequence has been replaced with a chimeric sequence containing rat insulin and human IL-2 leader sequences (see Tables 2, 3 and 4). This chimeric leader sequence enhances IL-2 gene expression.

5 To construct the LXSN-RI-IL2 vector, the bacterial plasmid pBC12/CMV/IL2 (Cullen, B.R., DNA 7:645-650, 1988, which is incorporated herein by reference) containing the full-length IL-2 cDNA and chimeric leader
10 sequence was digested with HindIII and the ends were blunted using Klenow polymerase. IL-2 cDNA was subsequently released from the plasmid by digestion with BamHI. The IL-2 fragment was purified by electrophoresis in a 1% agarose gel and the appropriate band was extracted
15 utilizing a glass powder method. Briefly, the gel slice was dissolved in 4M NaI at 55°. After cooling to room temperature, 4 µl of oxidized silica solution (BIO-101, La Jolla, CA) was added to adsorb the DNA. The silica was
20 ythen washed with a cold solution of 50% ethanol containing 0.1 M NaCl in TE buffer. The DNA was eluted from the silica by heating at 55° in distilled H₂O. The purified IL-2 cDNA was then directionally ligated into the HpaI-BamHI cloning sites of the pLXSN vector. A more complete description of the pLXSN-RI-IL2 vector and its partial nucleotide sequence are provided in Tables 2, 3, 4, 5 and
25 6.

Table 2

Description of the LXSNI-RI-IL2
from position 1 to 6365

<u>Bases</u>	<u>Description</u>
1-589	Moloney murine sarcoma virus 5' LTR
659-1458	The sequence of the extended packaging signal
1469-2151	IL-2 cDNA with chimeric leader sequence
1469-1718	IL-2 chimeric leader sequence
1647-1718	coding region of the signal peptide
1719-2151	Mature IL-2 coding sequence
2158-2159	Mo mu sarcoma virus end/SV 40 start
2159-2503	Simian virus 40 early promoter
2521-2522	Simian virus DNA end/Tn5 DNA start
2557-3351	Neomycin phosphotransferase
3370-3371	Tn5 DNA end/Moloney murine leukemia virus start
3411-4004	Moloney murine leukemia virus 3' LTR
4073-4074	Moloney murine leukemia DNA end/pBR322 DNA start
4074-6365	Plasmid backbone

Table 3

Enzyme	[# Cuts]	Position(s)
Aat1	[2]	1961, 2481
Aat2	[2]	811, 6295
Acc1	[1]	4252
Acc2	[19]	392, 394, 445, 969, 971, 1193, 2751, 3052, 3084, 3807, 3809, 4081, 4083, 4186, 4527, 5108, 5438, 5931, 6263
Acy1	[5]	808, 2685, 3860, 5910, 6292
Afl1	[13]	260, 273, 328, 626, 756, 1277, 3201, 3676, 3689, 3744, 4041, 5511, 5733
Afl2	[4]	34, 1064, 1955, 3446
Afl3	[2]	1592, 4480
Aha1	[20]	161, 237, 473, 474, 602, 644, 789, 2689, 2849, 3578, 3653, 3888, 3889, 4017, 4059, 4126, 4161, 4860, 5556, 5907
Aha2	[5]	808, 2685, 3860, 5910, 6292
Aha3	[3]	5239, 5258, 5950
Alu1	[33]	29, 33, 119, 190, 411, 654, 734, 742, 1470, 1486, 1751, 1935, 2003, 2446, 2500, 2791, 3249, 3441, 3445, 3532, 3607, 3826, 4069, 4122, 4141, 4422, 4648, 4738, 4784, 5041, 5562, 5662, 5725
Alw1	[20]	1110, 1414, 1665, 2018, 2147, 2160, 2529, 2553, 2864, 2929, 3110, 4027, 5041, 5127, 5129, 5225, 5226, 5689, 6006, 6010
AlwNI	[4]	231, 3572, 3647, 4896
Aoc1	[2]	847, 1076
Aoc2	[19]	323, 413, 426, 597, 1583, 1721, 2631, 2724, 2798, 2988, 3050, 3739, 3828, 3841, 4012, 4300, 4798, 5959, 6044
Aos1	[2]	2787, 5595
ApaL1	[4]	1717, 4296, 4794, 6040

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Apy1	[22]	315,	623,	801,	814,	1227,	1252,
		1275,	1295,	1325,	1526,	1536,	1558,
		2196,	2251,	2268,	3072,	3731,	4038,
		4629,	4642				4508,
Aqu1	[6]	241,	472,	1998,	3821,	3854,	3887
Ase1	[2]	1801,	5545				
Asp700	[1]	5972					
Asp718	[2]	476,	3891				
AspA1	[1]	1145					
Asu1	[29]	169,	200,	245,	260,	273,	328,
		626,	756,	826,	839,	1043,	1254,
		1532,	1649,	3201,	3541,	3586,	3616,
		3676,	3689,	3744,	4041,	5415,	5494,
		5733,	6349				5511,
Ava1	[6]	241,	472,	1998,	3821,	3854,	3887
Ava2	[13]	260,	273,	328,	626,	756,	1277,
		3201,	3676,	3689,	3744,	4041,	5511,
							5733
Ava3	[2]	2232,	2304				
Avr2	[2]	1962,	2482				
Ball	[3]	658,	1169,	2767			
BamH1	[1]	2152					
Ban1	[9]	318,	476,	1200,	2684,	2719,	3734,
		3859,	3891,	5321			
Ban2	[8]	413,	426,	597,	1583,	3050,	3828,
		3841,	4012				
Bbe1	[2]	2688,	3863				
Bbv1	[22]	969,	997,	1738,	2493,	2632,	2758,
		2800,	2816,	2909,	3321,	4060,	4131,
		4372,	4390,	4809,	4899,	4902,	5108,
		5600,	5802				5411,
Bcl1	[1]	2526					
Bgl1	[2]	2435,	5493				
Bspl286I	[19]	323,	413,	426,	597,	1583,	1721,
		2631,	2724,	2798,	2988,	3050,	3739,
		3841,	4012,	4300,	4798,	5959,	6044

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BspH1	[3]	5200,	6208,	6313		
BspM1	[4]	1501,	2500,	2572,	2953	
BssH2	[4]	392,	443,	3082,	3807	
BstE2	[1]	1145				
BstN1	[	22]	315,	623,	801,	814,	1227, 1252,
			1275,	1295,	1325,	1526,	1536, 1558, 1630,
			2196,	2251,	2268,	3072,	3731, 4038, 4508,
			4629,	4642			
BstU1	[	19]	392,	394,	445,	969,	971, 1193,
			2751,	3052,	3084,	3807,	3809, 4081, 4083,
			4186,	4527,	5108,	5438,	5931, 6263
BstX1	[	1]	2060				
BstY1	[	11]	2010,	2152,	2521,	2856,	3102, 5121,
			5132,	5218,	5230,	5998,	6015
Bsu36I	[	2]	847,	1076			
Ccr1	[	1]	1998				
Cfo1	[	31]	394,	396,	445,	447,	714, 971,
			2679,	2687,	2751,	2788,	3054, 3084, 3086,
			3314,	3809,	3811,	3862,	4083, 4186, 4216,
			4357,	4390,	4660,	4727,	4827, 5001, 5110,
			5503,	5596,	5933,	6265	
Cfr1	[	9]	656,	790,	1167,	1188,	2591, 2765,
			3156,	3183,	5761		
Cfr10I	[	3]	3004,	3185,	5453		
Cfr13I	[	29]	169,	200,	245,	260,	273, 328,
			626,	756,	826,	839,	1043, 1254, 1277,
			1532,	1649,	3201,	3541,	3586, 3616, 3661,
			3676,	3689,	3744,	4041,	5415, 5494, 5511,
			5733,	6349			
Cvn1	[	2]	847,	1076			
Dde1	[	23]	75,	165,	191,	282,	553, 847,
			1076,	1348,	1692,	2442,	3348, 3487, 3582,
			3657,	3698,	3879,	3967,	4290, 4755, 5164,
			5330,	5870,	6296		
Dpn1	[	30]	95,	1104,	1236,	1421,	1659, 2012,
			2154,	2523,	2528,	2547,	2858, 2936, 3017,
			3026,	3104,	3507,	4021,	5048, 5123, 5134,
			5142,	5220,	5232,	5337,	5678, 5696, 5742,
			6000,	6017,	6053		

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Dra1	[3]	5239,	5258,	5950		
Dra2	[4]	328,	1277,	3744,	6349	
Eae1	[9]	656,	790,	1167,	1188,	2591, 2765,
			3156,	3183,	5761		
Eag1	[	2]	790,	2591			
Eco47I	[	13]	260,	273,	328,	626,	756, 1277,
			3201,	3676,	3689,	3744,	4041, 5511, 5733
Eco52I	[	2]	790,	2591			
Eco81I	[	2]	847,	1076			
EcoN1	[	2]	850,	1450			
EcoO109I	[	4]	328,	1277,	3744,	6349	
EcoR1	[	1]	1460				
EcoR1*	[	14]	938,	1037,	1460,	1798,	1805, 1928,
			2064,	2121,	2236,	2308,	2400, 5240, 5546,
			5801				
EcoR2	[	22]	313,	621,	799,	812,	1225, 1250,
			1273,	1293,	1323,	1524,	1534, 1556, 1628,
			2194,	2249,	2266,	3070,	3729, 4036, 4506,
			4627,	4640			
EcoR5	[	4]	137,	213,	3554,	3629	
EcoT22I	[	2]	2232,	2304			
Fdi2	[	2]	2787,	5595			
Fnu4H1	[	41]	793,	967,	983,	986,	1191, 1752,
			2430,	2507,	2594,	2646,	2657, 2747, 2752,
			2789,	2830,	2917,	2920,	2923, 3159, 3255,
			3296,	3310,	4074,	4120,	4217, 4270, 4386,
			4404,	4407,	4525,	4680,	4823, 4888, 4891,
			5097,	5425,	5614,	5764,	5791, 5886, 6115
FnuD2	[	19]	392,	394,	445,	969,	971, 1193,
			2751,	3052,	3084,	3807,	3809, 4081, 4083,
			4186,	4527,	5108,	5438,	5931, 6263
Fok1	[	13]	498,	1198,	1358,	1679,	2333, 2552,
			3009,	3034,	3912,	4168,	5339, 5520, 5807
Fsp1	[2]	2787,	5595			
Hae2	[4]	2688,	3863,	4358,	4728	

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Hae3	[35]	171,	202,	247,	658,	792,	828,
	840,	1045,	1169,	1190,	1255,	1534,	1650,
	1866,	1961,	2423,	2429,	2438,	2481,	2593,
	2767,	3158,	3185,	3543,	3588,	3618,	3663,
	4495,	4506,	4524,	4958,	5416,	5496,	5763,
	6350						
Hap2	[30]	161,	237,	473,	601,	643,	789,
	2590,	2667,	2689,	2717,	2848,	2938,	3005,
	3186,	3578,	3653,	3888,	4016,	4058,	4126,
	4160,	4687,	4834,	4860,	5050,	5454,	5488,
	5555,	5665,	5907				
Hga1	[8]	455,	707,	960,	1580,	4175,	4591,
	5169,	5899					
HgiA1	[9]	413,	1721,	2798,	2988,	3828,	4300,
	4798,	5959,	6044				
Hha1	[31]	394,	396,	445,	447,	714,	971,
	2679,	2687,	2751,	2788,	3054,	3084,	3086,
	3314,	3809,	3811,	3862,	4083,	4186,	4216,
	4357,	4390,	4660,	4727,	4827,	5001,	5110,
	5503,	5596,	5933,	6265			
HinP1	[31]	392,	394,	443,	445,	712,	969,
	2677,	2685,	2749,	2786,	3052,	3082,	3084,
	3312,	3807,	3809,	3860,	4081,	4184,	4214,
	4355,	4388,	4658,	4725,	4825,	4999,	5108,
	5501,	5594,	5931,	6263			
Hinc2	[1]	5914					
Hind2	[1]	5914					
Hind3	[1]	2498					
Hinf1	[14]	298,	517,	857,	868,	1553,	1814,
	3170,	3304,	3356,	3881,	4380,	4455,	4851,
	5368						
Hpa2	[30]	161,	237,	473,	601,	643,	789,
	2590,	2667,	2689,	2717,	2848,	2938,	3005,
	3186,	3578,	3653,	3888,	4016,	4058,	4126,
	4160,	4687,	4834,	4860,	5050,	5454,	5488,
	5555,	5665,	5907				
Hph1	[11]	1214,	1240,	1817,	2863,	4102,	4111,
	5216,	5443,	5859,	6065,	6100		
Kpn1	[2]	480,	3895				
Mae1	[15]	30,	293,	689,	727,	739,	1452,
	1606,	1893,	1963,	2483,	3442,	3709,	4975,
	5228,	5563					

Mae2	[11]	808, 1139, 1180, 1987, 2801, 2988,
		4233, 5183, 5599, 5972, 6292
Mae3	[20]	38, 1052, 1080, 1145, 1289, 1478,
		1706, 2805, 3111, 3450, 4134, 4229, 4836,
		4899, 5015, 5298, 5629, 5687, 5840, 6028
Mbo1	[30]	93, 1102, 1234, 1419, 1657, 2010,
		2152, 2521, 2526, 2545, 2856, 2934, 3015,
		3024, 3102, 3505, 4019, 5046, 5121, 5132,
		5140, 5218, 5230, 5335, 5676, 5694, 5740,
		5998, 6015, 6051
Mbo2	[17]	444, 1145, 1356, 1575, 1617, 1908,
		1911, 3046, 3256, 3336, 4351, 5142, 5213,
		5968, 6046, 6155, 6351
Mnl1	[54]	291, 444, 508, 534, 560, 639,
		841, 939, 1227, 1330, 1363, 1369, 1372,
		1378, 1408, 1411, 1426, 1433, 1449, 1559,
		1620, 1909, 1921, 2412, 2418, 2443, 2449,
		2455, 2458, 2470, 2508, 2535, 2599, 2735,
		3092, 3286, 3707, 3859, 3878, 3923, 3948,
		3974, 4054, 4087, 4117, 4379, 4587, 4662,
		4911, 5311, 5392, 5540, 5746, 6339
Mse1	[22]	35, 1065, 1177, 1207, 1231, 1801,
		1843, 1956, 1971, 2124, 2139, 3447, 4261,
		5186, 5238, 5243, 5257, 5310, 5545, 5584,
		5949, 6321
Msp1	[30]	161, 237, 473, 601, 643, 789,
		2590, 2667, 2689, 2717, 2848, 2938, 3005,
		3186, 3578, 3653, 3888, 4016, 4058, 4126,
		4160, 4687, 4834, 4860, 5050, 5454, 5488,
		5555, 5665, 5907
Mst1	[2]	2787, 5595
Mst2	[2]	847, 1076
Mval	[22]	315, 623, 801, 814, 1227, 1252,
		1275, 1295, 1325, 1526, 1536, 1558, 1630,
		2196, 2251, 2268, 3072, 3731, 4038, 4508,
		4629, 4642
Nae1	[1]	3187
Nar1	[2]	2685, 3860
Nci1	[20]	161, 237, 473, 474, 602, 644,
		789, 2689, 2849, 3578, 3653, 3888, 3889,
		4017, 4059, 4126, 4161, 4860, 5556, 5907
Nco1	[2]	2389, 3117

Nde1 [1] 4303
 Nde2 [30] 93, 1102, 1234, 1419, 1657, 2010,
 2152, 2521, 2526, 2545, 2856, 2934, 3015,
 3024, 3102, 3505, 4019, 5046, 5121, 5132,
 5140, 5218, 5230, 5335, 5676, 5694, 5740,
 5998, 6015, 6051
 Nhe1 [3] 29, 1605, 3441
 Nla3 [26] 61, 1263, 1596, 1649, 1835, 1856,
 2030, 2230, 2302, 2393, 2559, 2904, 3090,
 3121, 3147, 3473, 4119, 4224, 4484, 5204,
 5695, 5705, 5783, 5819, 6212, 6317
 Nla4 [28] 153, 246, 262, 320, 478, 627,
 758, 827, 959, 1202, 1279, 2154, 2200,
 2272, 2686, 2721, 3678, 3736, 3861, 3893,
 4042, 4512, 4551, 5323, 5417, 5458, 5669,
 6259
 Nsi1 [2] 2232, 2304
 Nsp(7524)1 [8] 1596, 1835, 1856, 2230, 2302, 3090,
 4119, 4484
 Nsp(7524)2 [19] 323, 413, 426, 597, 1583, 1721,
 2631, 2724, 2798, 2988, 3050, 3739, 3828,
 3841, 4012, 4300, 4798, 5959, 6044
 NspB2 [12] 119, 190, 1751, 2158, 2791, 3532,
 3607, 3989, 4192, 4822, 5067, 6008
 NspH1 [8] 1596, 1835, 1856, 2230, 2302, 3090,
 4119, 4484
 PaeR7I [1] 1998
 Pal1 [35] 171, 202, 247, 658, 792, 828,
 840, 1045, 1169, 1190, 1255, 1534, 1650,
 1866, 1961, 2423, 2429, 2438, 2481, 2593,
 2767, 3158, 3185, 3543, 3588, 3618, 3663,
 4495, 4506, 4524, 4958, 5416, 5496, 5763,
 6350
 Ple1 [7] 865, 1547, 3350, 3889, 4374, 4859,
 5362
 PpuM1 [3] 328, 1277, 3744
 Pss1 [4] 331, 1280, 3747, 6352
 Pst1 [6] 987, 1163, 1888, 2511, 2738, 5618
 Pvu1 [1] 5743

Pvu2	[6]	119,	190,	1751,	2791,	3532,	3607
Rsa1	[10]	347,	478,	725,	1342,	1519,	1597,
	2991,	3893,	4288,	5853			
Rsr2	[1]	3201					
Sac1	[2]	413,	3828				
Sau1	[2]	847,	1076				
Sau3A1	[30]	93,	1102,	1234,	1419,	1657,	2010,
	2152,	2521,	2526,	2545,	2856,	2934,	3015,
	3024,	3102,	3505,	4019,	5046,	5121,	5132,
	5140,	5218,	5230,	5335,	5676,	5694,	5740,
	5998,	6015,	6051				
Sau96I	[29]	169,	200,	245,	260,	273,	328,
	626,	756,	826,	839,	1043,	1254,	1277,
	1532,	1649,	3201,	3541,	3586,	3616,	3661,
	3676,	3689,	3744,	4041,	5415,	5494,	5511,
	5733,	6349					
Scal	[1]	5853					
ScrF1	[42]	161,	237,	315,	473,	474,	602,
	623,	644,	789,	801,	814,	1227,	1252,
	1295,	1325,	1526,	1536,	1558,	1630,	2196,
	2251,	2268,	2689,	2849,	3072,	3578,	3653,
	3731,	3888,	3889,	4017,	4038,	4059,	4126,
	4161,	4508,	4629,	4642,	4860,	5556,	5907
Sdu1	[19]	323,	413,	426,	597,	1583,	1721,
	2631,	2724,	2798,	2988,	3050,	3739,	3828,
	3841,	4012,	4300,	4798,	5959,	6044	
Sec1	[38]	159,	235,	314,	324,	472,	536,
	621,	622,	760,	799,	800,	812,	813,
	1294,	1303,	1323,	1324,	1525,	1557,	1962,
	2194,	2266,	2389,	2424,	2433,	2482,	2848,
	3117,	3576,	3651,	3730,	3740,	3887,	3950,
	4036,	4037,	4640				
SfaN1	[23]	258,	520,	997,	1657,	2107,	2239,
	2311,	2643,	2898,	2984,	3048,	3114,	3323,
	3674,	3934,	4146,	4281,	4317,	4357,	4577,
	5629,	5820,	6069				
Sfi1	[1]	2435					
Sma1	[2]	474,	3889				
Spe1	[1]	726					
Sph1	[4]	1835,	2230,	2302,	3090		

Sspl	[	1]	6177						
Sst1	[	2]	413,	3828					
Stu1	[	2]	1961,	2481					
Styl	[	9]	324,	536,	1303,	1962,	2389,	2482,	
			3117,	3740,	3950				
Taq1	[	15]	860,	1096,	1407,	1418,	1660,	1999,	
			2514,	2798,	2954,	2978,	3014,	3176,	3367,
			4580,	6024					
Tha1	[	19]	392,	394,	445,	969,	971,	1193,	
			2751,	3052,	3084,	3807,	3809,	4081,	4083,
			4186,	4527,	5108,	5438,	5931,	6263	
Tth1111	[	6]	465,	877,	1275,	2803,	3880,	4227	
Xba1	[	2]	1892,	3708					
Xho1	[	1]	1998						
Xho2	[	11]	2010,	2152,	2521,	2856,	3102,	5121,	
			5132,	5218,	5230,	5998,	6015		
Xma1	[	2]	472,	3887					
Xma3	[	2]	790,	2591					
Xmn1	[	1]	5972						
Xor2	[	1]	5743						

Table 4

Enzymes which do not cut LXS NR II.L2:

Acc3	Bgl2	Cla1	Hpa1	Nru1
SnaB1				
Apa1	Bsm1	Dra3	Mlu1	PflM1
Spl1				
Asu2	BspM2	Eco47III	Mro1	Sac2
Sst2				
Ban3	BstB1	Esp1	Not1	Sal1

Asu1	--33--	112--	1-11--	11--	1--	1--	241--	1--	12--	1--	1--
Ava1	--1--	1--	1--	1--	1--	1--	21--	1--	1--	1--	1--
Ava2	--3--	11--	1--	1--	1--	1--	21--	1--	1--	1--	1--
Ava3	--	1--	1--	11--	1--	1--	1--	1--	1--	1--	1--
Avr2	--	1--	1--	1--	1--	1--	1--	1--	1--	1--	1--
Ba11	--	1--	1--	1--	1--	1--	1--	1--	1--	1--	1--
BamH1	--	1--	1--	1--	1--	1--	111--	1--	1--	1--	1--
Ban1	--	11--	1--	1--	1--	1--	2--	1--	1--	1--	1--
Ban2	--	1--	1--	1--	1--	1--	1--	1--	1--	1--	1--
Bbe1	--	1--	1--	1--	1--	1--	111--	2--	12+1--	1--	1--
Bbv1	--	2--	1--	1--	1121--	1--	1--	1--	1--	1--	1--
Bcl1	--	1--	1--	1--	1--	1--	1--	1--	1--	1--	1--
Bgl1	--	1--	1--	1--	1--	1--	1--	1--	1--	1--	1--
Bsp1286I	--	111--	1--	1--	111--	11--	12--	1--	1--	1--	11--
BspH1	--	1--	1--	1--	1--	1--	1--	1--	1--	1--	1--
BspM1	--	1--	1--	1--	1--	1--	1--	1--	1--	1--	1--
BssH2	--	11--	1--	1--	1--	1--	1--	1--	1--	1--	1--
BstE2	--	1--	1--	1--	1--	1--	1--	1--	1--	1--	1--
BstN1	--	1--	1--	23--	31--	1--	1--	1--	1--	1--	1--
BstU1	--	21--	2--	1--	1--	1--	2--	21--	1--	1--	1--
BstX1	--	1--	1--	1--	1--	1--	1--	1--	1--	1--	1--
BstY1	--	1--	1--	1--	1--	1--	1--	1--	112--	2--	1--
Bsu36I	--	1--	1--	1--	1--	1--	1--	1--	1--	1--	1--
Ccr1	--	1--	1--	1--	1--	1--	1--	1--	1--	1--	1--
Cfo1	--	22--	1--	1--	1--	211--	3--	1111--	111--	11--	1--
Cfr1	--	1--	1--	11--	1--	1--	1--	2--	1--	1--	1--
Cfr10I	--	1--	1--	1--	1--	1--	1--	1--	1--	1--	1--
Cfr13I	--	33--	112--	1-11--	11--	1--	1--	241--	1--	12--	1--
Cvn1	--	111--	1--	1--	1--	1--	1--	1111--	11--	1--	1--
Dde1	--	1--	1--	1--	1--	1--	1--	1--	1--	1--	1--
Dpn1	--	1--	1--	1--	1--	1--	3--	212--	1--	2221--	21--
Dra1	--	1--	1--	1--	1--	1--	1--	1--	1--	2--	1--
Dra2	--	1--	1--	1--	1--	1--	1--	1--	1--	1--	1--
Eae1	--	1--	1--	1--	1--	1--	1--	1--	1--	1--	1--
Eag1	--	1--	1--	1--	1--	1--	1--	1--	1--	1--	1--
Eco47I	--	3--	11--	1--	1--	1--	1--	1--	21--	1--	1--
Eco52I	--	1--	1--	1--	1--	1--	1--	1--	1--	1--	1--

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[illegible]

Table 5 (Cont'd)

from 1 to 6363. Numbered from position 1.

LASHN112	-----1000+-----2000+-----3000+-----4000+-----5000+-----6000+-----
-NucV 5' long ter	----->
(Splice)	>----->
1 to 63	>----->
macayala phosphota	----->
-NucV 3' long ter	----->
signal	1----->
Asp710	-----1----->
AspA1	-----1----->
Asu1	-----111+-----11----->
Ava1	-----1-----111+-----241+----->
Ava2	-----1-----11-----21+----->
Ava3	-----1-----11-----21+----->
Ava2	-----1-----11----->
Bal1	-----1-----1----->
BanH1	-----1-----1----->
Ban1	-----1-----1----->
Ban2	-----11+-----11----->
Bbo1	-----1-----1-----2+----->
Bbv1	-----1-----1-----1----->
Bcl1	-----1-----1-----111+-----12+----->
Bgl1	-----1-----1----->
Bsp12061	-----111+-----1-----11----->
BspA1	-----1-----1-----11----->
BspM1	-----1-----1-----1----->
BseK2	-----11-----1-----1----->

Table 5 (Cont'd)

from 1 to 6363. Numbered from position 1.

LSHNR112	-----1000+-----2000+-----3000+-----4000+-----5000+-----6000+-----
-MAY 5' long ter	----->
[Splice]	
1 t 603 of R112	
neomycin phosphota	
-MAY 3' long ter	
signal	1 2 ----->
ECOT221	-----+-----

from 1 to 6365. Numbered from position 1.

house_DNA_end/MO-MuSV_DNA_start_[split]

>Nhe1 >Afl2

10 20 30 40 50 60 70

TTTGAAGAC CCCACCGTA GGTGGCAAGC TAGCTTAAGT AACGCCACTT TGCAAGCCAT CGAAAAATAC
AAACTTTCTG GGGTGGGCAAT CCACCGTTGG ATCGAATTCA TTGCGGTGAA ACGTTCGGTA CCTTTTATG

>Pvu2
>NspB2
>EcoR5

80 90 100 110 120 130 140

ATAACTGACA ATAGGAAAGT TCAGATCAAG GTCAGGAACA AAGAAACAGC TGAATACCA ACAGGATATC
TATGACTCT TATCGTTTCA AGTCTAGTTC CAGTCCTGT TTCTTTGTGG ACTTATGGTT TGTCCTATAG

>Pvu2
>NspB2

150 160 170 180 190 200 210

TGTCGTAAAC GGTTCCTGCC CCGGCTCAGC GCCAAGAACG CATGAGACAG CTCAGTGCAT GCCCAAACAG
ACACCATTCG CCAAGGACCG GCGCGAGTCC CCGTTCTTCT CTACTCTGTC GACTCACTAC CCGGTTTGTG

>Ava1
>EcoR5
>AluM1
>Apu1

220 230 240 250 260 270 280

GATATCTGTG GTAAGCAGTT CCGCCCCCGG CTGGGGGCGA AGAACAGATG GTCCCCAGAT CGGGTCCAGC
CTATAGACAC CATTCGTCAA GCGCGGGGCG GAGCCCCGGT TCTTGTCTAC CAGCGGTCTA CCGCAGGTGG

>PpuM1
>Dra2
>EcoO109I
>Bam1
>Sty1
>Pss1
>Rsa1

290 300 310 320 330 340 350

CCTCAGCAGT TTCTAGTCAA TCATCAGATG TTTCAGCGGT GCGCCAAAGC CCTGAAATG ACCCTGTACG
CGAGTGTCTA AAGATCACTT AGTAGTCTAC AAAAGTCCCA CCGCGTTGCT GGACTTTTAC TCGACATGG



>Cfr1
 .
 >Eae1
 .
 >extended_packaging_signal
 .
 640 650 660 670 680 690 700

 ACCGACCCAC CACCGGGAGG TAGCTGGOC AGCAACTTAT CTGTGTCTGT COGATTGTCT AGTGTCTATG
 TGGCTGGGTG GTGGCCCTOC ATTGCACGG TCGTTGAATA GACACAGACA GGCTAACAGA TCACAGATAC

>Spe1
 .
 >Hga1
 .
 710 720 730 740 750 760 770

 TTGATGTTA TCGGCTTCC TCTGTACTAG TTAGCTAACT AGCTCTGTAT CTGGGGACC CGTGGTCGAA
 AACTACAAT ACGCGAGCC ACACATGATC AATCGATTGA TCGACACATA GACCGCCTCG GCACCACCTT

>Eco52I
 .
 >Cfr1
 .
 >Xma3
 .
 >Eag1
 .
 >Eae1
 .
 780 790 800 810 820 830 840

 CTGACGAGTT CTGAACACC GCGGCCAAC CTGGCAGAC TCCACGGAC TTGCGGGGC GTTTTGTGG
 GACTOCTCAA GACTTGTGG GCGCGTTGG GACCTCTOC ACCGTCCCTG AAGCCCCCG GAAAAACAC

>EcoN1
 .
 >Bsu36I
 .
 >Aoc1
 .
 >Bsu1
 .
 >Eco81I
 .

Table 6 (Cont'd)

>Cvn1
 ^
 >Not2
 ^
 | 850 860 870 880 890 900 910

 CCGGACCTGA GGAAGGGAGT CGATGTGGAA TCCGACCCCG TCAGGATATG TGGTTCTGCT ACCAGACGAG
 GGGCTGGACT CCTTCCCTCA GCTACACCTT AGGCTCGGGC AGTCCTATAC ACCAAGACCA TCCTCTGCTC

>Hga1
 ^
 920 930 940 950 960 970 980

 AACCTAAAAC AGTTCCCGCC TCCGTCTGAA TTTTTCCTTT CCGTTTGGAA CCGAAGCCGC CGGTCTTGTG
 TTGGATTTTG TCAAGCGCGG AGGCAGACTT AAAAACGAAA GCGAAACCTT CGCTTCGGCG CCGAGAACAG

>Pst1
 ^
 | 990 1000 1010 1020 1030 1040 1050

 TGCTGCAGCA TCGTTCTGTG TTGTCTCTGT CTGACTGTGT TTCTGTATTT GTCTGAAAAT TAGGGCCAGA
 ACGACGTCGT AGCAAGACAC AACAGAGACA GACTGACACA AAGACATAAA CAGACTTTTA ATCCCGGTCT

>Acl1
 ^
 >Sma1
 ^
 >Cvn1
 ^
 >Not2
 ^
 >Bsu361
 ^
 >Afl2 >Eco811
 ^ ^
 1060 1070 1080 1090 1100 1110 1120

 CTGTTACCAC TCCCTTAAGT TTCACTTAAO GTCACTGGAA AGATGTGGAG CCGATCGCTC ACAACCACTC
 GACAAATGCTG AGCGAATTCA AACTCGAATC CAGTGAOCTT TCTACAGCTC CCGTAGCGAG TGTTCGTCAG

>Cfr1
 ^
 >AspA1 >Eae1 >Eae1
 ^ ^ ^

Table 6 (Cont'd)

>Hae2 >BstE2 >Pst1 >Bcl1 >Hae2 >Cfr1
 1130 1140 1150 1160 1170 1180 1190
 CCGTACATGTC AACAAGAGAC GTTGGGTTAC CTTCTGCTCT GCAGAATGCC CAACCTTTAA CGTCCGATCG
 CCATCTACAG TTCCTCTCTG CAACCCAATG CAAGACGAGA CGTCTTACCG GTTCGAAATT GCAGCCTACC

>Bam1 >Hph1 >Hph1
 1200 1210 1220 1230 1240 1250 1260
 CCGCGAGACG GCACCTTTAA CCGAGACCTC ATCACCACGG TTAAGATCAA GGTCTTTTCA CCTGGCCCGC
 CGCGCTCTGC CGTGGAAATT GGCTCTGCAG TAGTGGGTCC AATTCTAGTT CCAGAAAAGT GGACCGGGCG

>Pss1
 >Dra2
 >EcoO109I
 >PpuM1
 >Tth1111I >StyI
 1270 1280 1290 1300 1310 1320 1330
 ATGGACACCC AGACCAGGTC CCGTACATCG TGACCTGGCA AGCCTTGGCT TTGACCCCC CTCCCTGGGT
 TACCTGTGGG TCTGGTCCAG GCGATGTAGC ACTGGACCT TCGGAACCGA AAATCTGGGG GAGCGACCCA

>Rsa1
 1340 1350 1360 1370 1380 1390 1400
 CAAGCCCTTT GTACACCTA AGCCTCCGGC TCCTCTTCTT CCATCCGGCC CGTCTCTCCC CTTTGAACCT
 GTTCGGGAAA CATCTCCGAT TCGGAGGGCG AGGACAAGCA GGTAGCGGGG GCAGAGACGG CGAACTTGGA

>EcoN1 >EcoRI
 1410 1420 1430 1440 1450 1460 1470
 CCTGCTTCCA CCGCGCTCG ATCTCCCTT TATCCAGCCC TCACTCCTTC TCTAGGCGCG AATTGGTTAG
 CGACCAAGCT CCGCGCGAGC TAGGAGGGAA ATAGGTCCGG AGTGAGGAAG AGATCCGCCC TTAACCAATC

Table 6 (Cont'd)

		>BspH1		>RsaI			
1480	1490	1500	1510	1520	1530	1540	
CTTGCTAAGT	GACCAGCTAC	AGTCGGAAAC	CATCAGCAAG	CAGGTATGTA	CTCTCCAGCG	TGGGCCTGGC	
AACCATTCA	CTGGTCGATG	TCAGCCTTTC	GTACTCGTTC	GTCCATACAT	GAGAGGTCCC	ACCCCGACCG	
				>RsaI			
				>NspH1			
				>Ban2		>Nsp(7524)1	
>PleI		>HgaI		>AflI		>KhaI	
1550	1560	1570	1580	1590	1600	1610	
TTCCCCAGTC	AAGACTCCAG	GGATTTCAGG	GAGGCTGTGG	GCTCTTCTCT	TACATGTACC	TTTTCCTACC	
AAGGGGTCAG	TTCTGAGGTC	CCTAAACTCC	CTCGGACACC	CGAGAAGACA	ATGTACATCG	AAAACGATCG	
1620	1630	1640	1650	1660	1670	1680	
CTCAACCCTG	ACTATCTTCC	AGGTCAITGT	TCCAACATCG	CCCTGTGGAT	CGACAGGATG	CAACTCCTGT	
AGTTGGGAC	TCATACAAGG	TCCAGTAACA	AGGTTGTACC	GGGACACCTA	GCTGTCTTAC	GTTGAGGACA	
		>HglAI					
		>ApaLI					
1690	1700	1710	1720	1730	1740	1750	
CTTGCAATTGC	ACTAAGTCTT	GCACCTGTCA	CAACACAGTCC	ACCTACTTCA	AGTTCTACAA	AGAAAACACA	
AACGTAAAG	TCATTCAAG	CGTCAACAGT	GTTTGTCAAG	TGGATGAAGT	TCAAGATGTT	TCTTTTGTGT	
>Pvu2		>NspB2		>AseI		>BphI	
1760	1770	1780	1790	1800	1810	1820	
GCTGCAACTG	GAGCAATTAC	TGCTGGATTT	ACAGATGATT	TTGAATGCAA	TTAATAATTA	CAAGAAATCCG	
CGACGTTGAC	CTCGTAAATG	ACGAOCTAAA	TGTCTACTAA	AACTTACCTT	AATTAITAAAT	GTTCTTAGCG	
>SphI		>Nsp(7524)1		>NspH1			
>NspH1		>Nsp(7524)1		>PstI			
1830	1840	1850	1860	1870	1880	1890	
AAACTCAOCC	GCATGCTCAC	ATTAAAGTTT	TACATGCCCA	AGAAGGCCAC	AGAACTGAAA	CATCTGCAAT	
TTTCACTGCC	CGTACGAGTG	TAAATTCAAA	ATGTACGGGT	TCTTCCCGTG	TCTTCACTTT	GTAGACGTCA	

Table 6 (Cont'd)

```

>Xba1
      |
      | 1900      1910      1920      1930      1940      1950      | 1960
      |  .      .      .      .      .      .      |  .
GTCTAGAAGA AGAACTCAAA CCTCTCGAGG AAGTCTTAAA TTAGCTCAA AGCAAAACT TTCACTTAAG
CAGATCTTCT TCTTCAGTTT GGAGACCTCC TTCACGATTT AAATCGAGTT TCGTTTTTGA AAGTGAATTC

>Afl12
      |

>Ave2
      |

>Sty1
      |

>Stu1
      |
>Aat1
      |
      | 1970      1980      1990      2000      2010      2020      2030
      |  .      .      .      .      .      .      |  .
GGCTAGGGAC TTAATCAGCA ATATCAAAGT AATAGTTCTC CAGCTAAAGG GATCTGAAAC AACATTCATG
CGGATCCCTG AATTAGTCGT TATAGTTCCA TTAACAAGAG CTCGATTTCC CTAGACTTTG TTGTAAGTAC

>BstX1
      |

      | 2040      2050      2060      2070      2080      2090      2100
      |  .      .      .      .      .      .      |  .
TGTGAATATG CTGATGAGAC AGCCACCAAT GTGCAATTC TGAACAGATG GATTACCTTT TGTCAAAGCA
ACACTTATAC GACTACTCTG TCGGTGGTAA CACCTTAAAG ACTTGTCTAC CTAATCGAAA ACAGTTTGGT

>BamH1
      |
>BstY1
      |
>Xho2
      |
>Hsp92
      |
>simian_virus_40_early_promoter
      |
>Mo-MuSV_DNA_end/simian_virus_40_DNA_start
      |
      | 2110      2120      2130      2140      2150      2160      2170
      |  .      .      .      .      .      .      |  .
TCATCTCAAC ACTAACTTGA TAATTAAAGT CTTCACACTT AAAACATATC AGGATCCGCT GTGGAATGTC
AGTAGAGTTG TGATTCAACT ATTAATTCAC GAAGCGTCAA TTTTGTATAO TCCTAGCGCA CACCTTACAC

>EcoT221
      |
>Hae1
      |
>Ava3
      |

```

Table 6 (Cont'd)

							>Hsp(7524)1	
							>HspH1	
							>Sph1	
2180	2190	2200	2210	2220	2230	2240	|	
•	•	•	•	•	•	•		
TGTCAGTTAC GGTGTGGAAA GTCCCCAGGC TCCCCAGCAG GCAGAAGTAT GCAAAGCATC CATCTCAATT							|	
ACAGTCAATC CCACACCTTT CAGCGGTCCG AGCGGTCTGC CGTCTTCATA CGTTTCTAC GTACAGTTAA							|	
							>Hsp(7524)1	
							>HspH1	
							>Sph1	
2250	2260	2270	2280	2290	2300	2310	|	
•	•	•	•	•	•	•		
AGTCAGCAAC CAGGTGTGCA AAGTCCCCAG GTCGCCAGC AGGCAGAACT ATGCAAGCA TGCATCTCAA							|	
TCAGTCTTC GTCCACACT TTCACGGCTC CCACGGCTCG TCCGTCTTCA TACGTTTCT ACGTAGAGTT							|	
							>Hsp(7524)1	
							>HspH1	
							>Sph1	
2320	2330	2340	2350	2360	2370	2380	|	
•	•	•	•	•	•	•		
TTAGTCAGCA ACCATAGTCC CCCCCCTAAC TCCGCCATC CCGCCCCCTAA CTCGCCAG TCCGCCAT							|	
AATCAGTCGT TCGTATCAG CCGGGGATT AGCGGGTAG GCGGGGATT GAGGGGGTC AAGCGGGTA							|	
							>Hco1	
							>Sty1	
2390	2400	2410	2420	2430	2440	2450	|	
•	•	•	•	•	•	•		
TCTCGCCCC ATCGCTGACT AATTTTTT ATTTATCCAG AGCGCGAGCC CGCTCGGCC TCTGAGCTAT							|	
AGAGCGCCCC TACCGACTCA TAAAAAAA TAATACGTC TCGCGTCCG CCGAGCCGC AACTCGATA							|	
							>Hco1	
							>Sty1	
							>Hvr2	
							>Stu1	
							>BspH1	

55

Table 6 (Cont'd)

2460 2470 2480 2490 2500 2510 2520
 TCCAGAAGTA GTCAGGACGC TTTTTCGAG CCCTAGGCTT TTGCAAAAAG CTTCGGCTCC ACGTCGAGGC
 ACGTCTTCAT CACTCCTCCG AAAAAACCTC CCGATCCGAA AACGTTTTTC GAACCCGACC TCCAGCTCCG

>AatI >Hind3 >PstI
 ↓ ↓ ↓

2530 2540 2550 2560 2570 2580
 GGATCTGATC AAGAGACAGC ATCAGGATCG TTTCGC ATG ATT CAA CAA GAT CGA TTC CAC GCA GGT TGT
 CCTAGACTAG TTCTCTGTCC TACTCCTAGC AAAGCG TAC TAA CTT GTT CTA CCT AAC GTG CGT CCA ACA
 Met Ile Glu Gln Asp Gly Leu His Ala Gly Ser>

>BclI
 ↓

>Xho2
 ↓

>BstY1
 ↓

Lmian_virus_DNA_end/Tn5_DNA_start
 ↓

>BspHI
 ↓

2590 2600 2610 2620 2630 2640 2650
 CCG GCC GCT TCG CTG CAG ACG CTA TTC CCG TAT CAC TCG GCA CAA CAG ACA ATC CCG TCG TGT
 CCG CCG CCA ACC CAC CTC TCG GAT AAG CCG ATA CTG ACC CGT GTT CTC TGT TAG CCG ACG ACG
 Pro Ala Ala Trp Val Glu Arg Leu Phe Gly Tyr Asp Trp Ala Gln Gln Thr Ile Gly Cys Ser>

>EcoS2I
 ↓

>EagI
 ↓

>EaeI
 ↓

>CfrI
 ↓

>Xma3
 ↓

>Hae2
 ↓

>BbeI
 ↓

>HaeI
 ↓

>AcyI
 ↓

>Aha2
 ↓

266 2670 2680 2690 2700 2710

GAT GCC GCC GTG TTC CCG CTG TCA GCG CAG CCG CCG CCG CTT CTT TTT GTC AAG ACC GAC CTG
CTA CCG CCG CAC AAG GCC GAC AGT CCG GTC CCC CCG CCG CAA GAA AAA CAG TTC TCG CTG GAC
Asp Ala Ala Val Phe Arg Leu Ser Ala Gln Gly Arg Pro Val Leu Phe Val Lys Thr Asp Leu>

>BamI

2720 2730 2740 2750 2760 2770

TCC GGT GCC CTG AAT CAA CTG CAG GAC GAG GCA CCG CCG CTA TCG TCG CTG GCG ACG ACG GCG
ACG CCA CCG GAC TTA CTT GAC GTC CTG CTC CGT CCG CCG GAT AGC ACC GAC CCG TCG TCG CCG
Ser Gly Ala Leu Asn Glu Leu Gln Asp Glu Ala Ala Arg Leu Ser Trp Leu Ala Thr Thr Gly>

>BamI >PstI >BclI >CfrI >EaeI

2780 2790 2800 2810 2820 2830 2840

TT CCT TGC CCA GGT GTG CTC CAC GTT GTC ACT CAA GCG CCA ACG GAC TCG CTG CTA TTC GCG
CAA CCA ACG CGT CCA CAC GAG CTC CAA CAG TGA CTT CCG CCT TCG CTG ACC GAC GAT AAC CCG
Val Pro Cys Ala Ala Val Leu Asp Val Val Thr Glu Ala Gly Arg Asp Trp Leu Leu Leu Gly>

>FspI >AseI >TthI >FdlI >PvuI >HglAI >HaeI >HspII

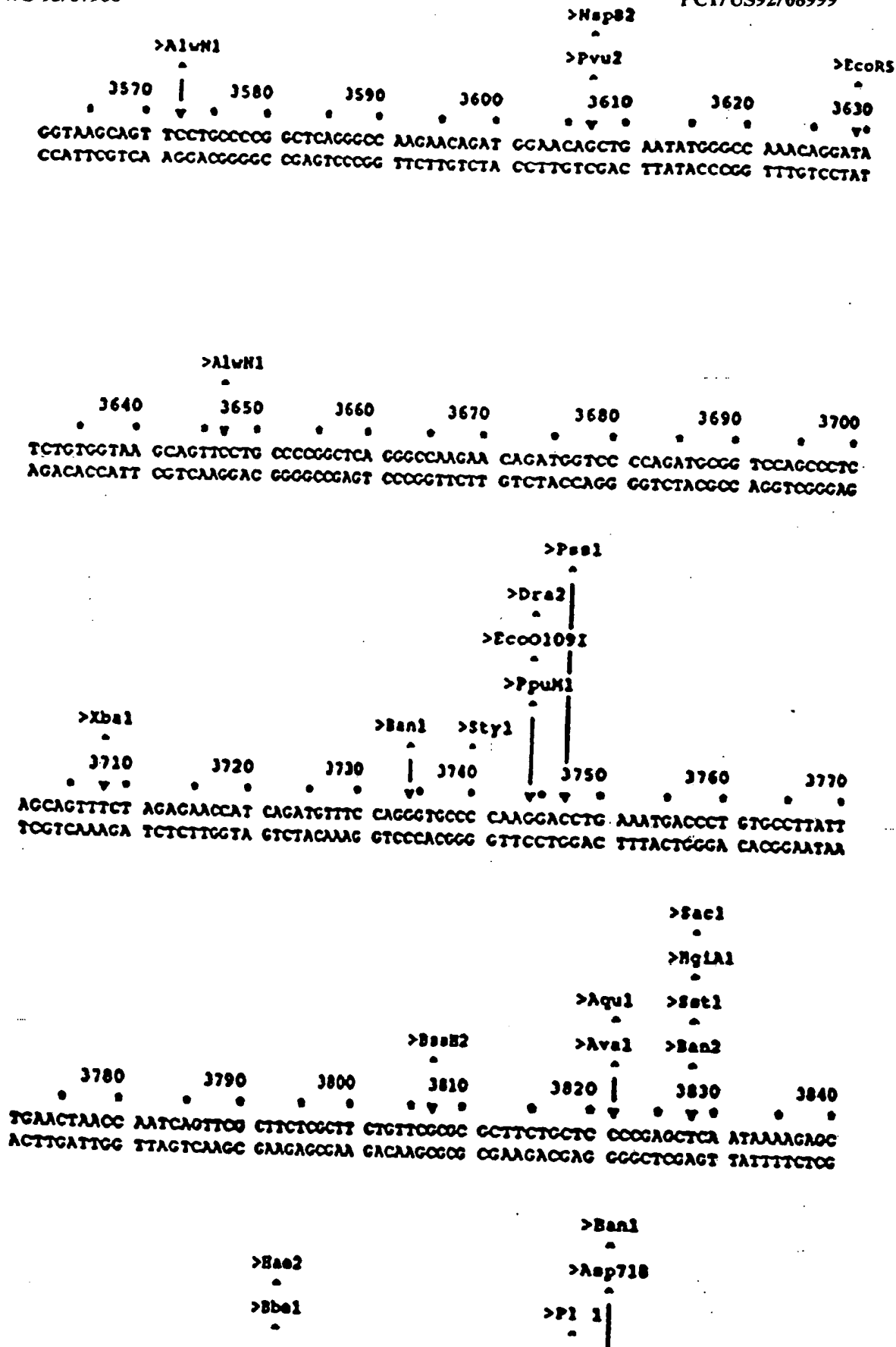
2850 2860 2870 2880 2890 2900

GAA TG CCG CCG CAG GAT CTC CTG TCA TCT CA CTT CCT CCT CCG CAG AAA GTA TCG ATC ATG
CTT CAC CCG CCG GTC CTA GAG GAC AGT AGA GTO CAA CCA CCA CCG CTC TTT CAT ACG TAG TAC
lu Val Pro Gly Gln Asp Leu Leu S r Ser His Leu Ala Pro Ala Glu Lys Val Ser Ile Met>

>BstI >XhoI >RphI >BspHI

Table 6 (Cont'd)

2910	2920	2930	2940	2950	2960
GCT GAT GCA ATG CCG CCG CTG CAT ACG CTT GAT CCG GCT ACC TGC CCA TTC GAC CAC CAA CCG	CGA CTA CGT TAC GCC GCC GAC GTA TGC GAA CTA CCG CGA TGC ACC CGT AAC CTG GTG GTT CCG	Ala Asp Ala Met Arg Arg Leu His Thr Leu Asp Pro Ala Thr Cys Pro Phe Asp His Gln Ala>			
		>RsaI			
		>HgiIA1			
		>Hae2			
			>Cfr101		
2970	2980	2990	3000	3010	3020
AAA CAT CCG ATC GAG CGA GCA CGT ACT CCG ATG GAA GCG CGT CTT CTC GAT CAG CAT CAT CTG	TTT GTA CCG TAG CTC CCT CGT GCA TGA CCG TAC CTT CCG CCA GAA CAG CTA GTC CTA CTA CAC	Lys His Arg Ile Glu Arg Ala Arg Thr Arg Met Glu Ala Gly Leu Val Asp Gln Asp Asp Leu>			
					>SphI
					>Hsp(7524)1
		>Bam2			
				>BsaH2	>HspH1
3040	3050	3060	3070	3080	3090
GAC GAA CAG CAT CAG CCG CTC CCG CCA CCG GAA CTG TTC CCG ACC CTC AAC CCG CCG ATG CCG	CTG CTT CTC GTA GTC CCC GAG CCG GGT CCG CTT GAC AAC CCG TCC CAG TTC CCG CCG TAC CCG	Asp Glu Glu His Gln Gly Leu Ala Pro Ala Glu Leu Phe Ala Arg Leu Lys Ala Arg Met Pro>			
		>Xho2			
		>BstY1			
		>HcoI			
		>StyI			
					>Cfr1
					>EaeI
3100	3110	3120	3130	3140	3150
GAC CCG GAG CAT CTC CTC CTC ACC CAT CCG CAT CCG TCC TTT CCG AAT ATC ATC CTC GAA AAT	CTG CCG CTC CTA CAG CAG CAC TCG GTA CCG CTA CCG ACC AAC CCG TTA TAG TAC CAC CTT TTA	Asp Gly Glu Asp Leu Val Val Thr His Gly Asp Ala Cys Leu Pro Asn Ile Met Val Glu Asn>			



>Styl
 3920 3930 3940 3950 3960 3970 3980
 AAGCTCTTGC AGTTCATCC GACTTGTGGT CTGGCTGTC CTTGGGAGGG TCTCTCTCA GTGATTGACT
 TGGGAGAACG TCAAGCTAGG CTGAACACCA GAGCGACAAG GAACCCCTCC AGAGGAGACT CACTAACTA

>Hsp82
 3990 4000 4010 4020 4030 4040 4050
 ACCGGTCAGC GGGGTCCTTT CATTTCGGGG CTCGTCGGGG ATCGGCAGAC CCGTCCCCAG GGACCACCGA
 TGGGCAGTCG CCCCCAGAAA GTAAACCCCG GAGCAGGCCG TAGCCCTCTG GGGACGGGTC CCTCGTGGCT

>Mo-MuLV_DNA_end/plasmid_pBR322_DNA_start
 4060 4070 4080 4090 4100 4110 4120
 CCCACCAACC GGAGGTATGC TGGCTGCCTC CGCGGTTTCC GTGATGACCG TCAAAACCTC TCACACATCC
 GGGTCGTCGC CCTCCATTCC ACCGACGGAG CGCGCAATGC CACTACTCCG ACTTTTCCAG ACTGCTATCC

4130 4140 4150 4160 4170 4180 4190
 AGCTCCCGCA GACGGTCACA GCTTGTCTGT AAGCGGATCC GCGGAGCAGA CAAGCCCGTC ACGCGCGGTC
 TCGAGGGGCT CTGCGAGTGT CGAACAGACA TTGCGCTACG GCGCTCGTCT GTTCGGCCAG TCCGCGCCAG

> Acc1

Table 6 (Cont'd)

↓ 4200 4210 4220 4230 ↓ 4240 4250 ↓ 4260
 ACGCGCTGTT GCGCGCTGTC GCGCGCCAGC CATGACCCAG TCACGTAGCG ATAGCCGAGT GTATACTGGC
 TCGCCACAA CCGCCACAG CCGCGCTCG GTACTCGGTC AGTGCATCGC TATCGCCTCA CATATGACCG

>HqLA1

>Rsa1

>Apa1

>Nde1

4270 4280 4290 4300 4310 4320 4330
 TTAACATATGC GGCATCAGAG CAGATTCTAC TCAGAGTGCA CCATATGCGG TGTGAAATAC CGCAGAGATG
 AATTGATAAG CCGTAGTCTC GTCTAACATG ACTCTCAAGT GGTATAAGCC ACACTTTATG CGGTGTCTAC

>Hae2

>Ple1

4340 4350 4360 4370 4380 4390 4400
 CGTAAGGAGA AAATACCGCA TCAGCGGCTC TTCGGCTTCC TCGCTCACTG ACTCGCTCGG CTGGGTGGTT
 GCATTCTCT TTTATCGCGT AGTCCGCGAG AAGCGGAAGG ACGGAGTGAC TCAGCGAGCG GAGCCAGCAA

4410 4420 4430 4440 4450 4460 4470
 CCGCTCGGGC GAGCGGTATC AGCTCACTCA AAGCGCGTAA TACGGTTATC CACAGAATCA GCGGATAAGC
 GCGGACGCG CTGCCATAG TCGAGTGAGT TTCCGCCATT ATGCCAATAG GTGTCTTAGT CCGCTATTGC

>Hsp(7524)1

>HspH1

>Afl3

4480 4490 4500 4510 4520 4530 4540
 CACGAAAGAA CATGTGACCA AAAGGCCAGC AAAGGCCAG GAACCGTAAA AAGCGCGCGT TCCTCGCGTT
 GTCTTTCTT GTACACTCGT TTTCGGGTGC TTTCGGGTGC CTTCGCCATT TTCCGGGCCA ACGACCGCAA

>Hga1

4550 4560 4570 4580 4590 4600 4610

Table 6 (Cont'd)

TTTCCATAGG CTCGGCCCCC CTCAGGAGCA TCACAAAAAT CCACCGCTCA GTACAGGCTG CCGAAACCCC
AAAGGTATCC GACGGCCCCG GACTGCTCGT AGTGTTTTTA GCTGCGAGTT CAGTCTCCAC CGCTTTCCG

4620 4630 4640 4650 4660 4670 4680
ACAGGACTAT AAAGATACCA GCGGTTTCCC CCTGGAAGCT CCCTCGTCCG CTCTCTGTT CCGACCCCTGC
TGTCTGATA TTTCTATGGT CCGCAAAGCG GGACCTTCGA GGGAGCACCG CAGAGGACAA GGCTGGGACG

>Hae2

4690 4700 4710 4720 4730 4740 4750
GCTTACCGG ATACCTGTCC GCGTTTCTCC CTTCGCGAAG CGTGGCGCTT TCTCATAGCT CACGCTGTAG
CGGAATGCC TATGGACAGG CCGAAAGAGG GAAGCCCTTC GCACCGCGAA AGAGTATCGA GTCCACATC

>HglA1

>ApaL1

4760 4770 4780 4790 4800 4810 4820
GTATCTCAGT TCGGTGTAGG TCGTTGGCTC CAAGCTCGGC TGTGTGCACG AACCCCGGT TACGCCCCAG
CATAGAGTCA AGCCACATCC AGCAAGCGAG GTTCGACCCG ACACACGTGC TTGGGGGCA AGTCCGGCTG

>NspB2

>Ple1

4830 4840 4850 4860 4870 4880 4890
CGCTGCGCT TATCCGTAAT CTATCGTCTT CAGTCCAAAC CGGTAAGACA CGACTTATCG CCACTGGCAG
CGCAGCGCGA ATAGGCCATT GATAGCAGAA CTCAGGTTCC GCCATTCTGT CCGAATAGC GGTGACGTC

>AlwN1

4900 4910 4920 4930 4940 4950 4960
CAGCCACTCG TAACAGCAAT AGCAGAGCGA GGTATGTAGG CCGTGCTACA GAGTTCTGA AGTGGTGGCC
GTGGGTGACC ATTGTCTTAA TCGTCTCGCT CCATACATCC GCCACGATGT CTCAGAACT TCACCACCGG

4970 4980 4990 5000 5010 5020 5030
TAACATCCGC TACACTAGAA CGACAGTATT TGGTATCTGC GCTCTGCTCA AGCCAGTTAC CTTCGAAAA
ATTGATGCCG ATGTGATCTT CCGTTCATAA ACCATAGACG CGAGACGACT TCGGTCAATC GAAGCCTTTT

>NspB2

WO 93/07906

Table 6 (Gont'd)

PCT/US92/08999

5040 5050 5060 5070 5080 5090 5100
 AGAGTTGCTA CCTCTTCATC CCGCAAACAA ACCACCGCTC GTACCGGTCC TTTTITTTCT TCCAAGCAGC
 TCTCAACCAT CGACAACCTAG GCGGTTTCTT TCGTGGCCAC CATCGCCACC AAAAAACAA ACGTTCTGTC

>Xh 2 >BstY1
 >BstY1 >Xho2 >Hga1
 5110 5120 5130 5140 5150 5160 5170
 AGATTACGGC CAGAAAAAA GGATCTCAAG AAGATCTTTT GATCTTTTCT ACGGGGTCTG ACGCTCAGTG
 TCTAATGGC GTCTTTTTT OCTAGAGTTC TTCTAGGAAA CTAGAAAAGA TCGCCACAGC TCGAGTCAC

>BstY1
 >Xho2 >BstY1 >Dra1
 >Hae2 >BspH1 >Hph1 >Xho2 >Aha3
 5180 5190 5200 5210 5220 5230 5240
 GAACGAAAC TCACGTTAAG GGATTTTGGT CATGACATTA TCAAAAAGGA TCTTCACCTA GATCCTTTTA
 CTTGCTTTTG AGTGCAATTC CCTAAAACCA GTACTCTAAT AGTTTTTCTT AGAAGTGGAT CTAGGAAAAAT

>Dra1
 >Aha3
 5250 5260 5270 5280 5290 5300 5310
 AATTAAAAAT GAAGTTTAA ATCAATCTAA AGTATATATG AGTAAACTTG GTCTGACAGT TACCAATGCT
 TTAATTTTTA CTTCAAAATT TAGTTAGATT TCATATATAC TCATTTGAAC CAGACTGTCA ATGCTTACGA

>Bam1 >Pst1
 5320 5330 5340 5350 5360 5370 5380
 TAATCAGTGA CGCACCTATC TCACGGATCT GTCTATTTGG TTCAATCCATA GTTGCTGAC TCGGCTGCT
 ATTAGTCACT CCGTGGATAG AGTGGCTAGA CAGATAAACC AAGTACGTAT CAAAGGACTG ACGGGCAGCA

>Hph1
 5390 5400 5410 5420 5430 5440 5450
 GTACATAACT ACGATAACCG AGGGCTTACC ATCTGGCCCG AGTCTGTCAA TGATACCGCG AGACCCACCG
 CATCTATTGA TGCTATGCCG TCCCGAATGG TAGACCGCCG TCAAGACGTT ACTATGGCGC TCTCGGTGCG

>Cfr101 >Bgl1
 5460 5470 5480 5490 5500 5510 5520
 TCACCGGCTC CAGATTATC AGCAATAAAC CAGCCAGCCG GAAGGGCCCG GCGCAGAAGT CGTCTGCCAA
 AGTGGCCGAG GTCTAAATA TCGTTATTTG GTGGGTGGCG CTTCGGCGCT CCGGTCTTCA CCAGCAAGTT

Table 6 (Cont'd)

>Ase1

5530	5540	5550	5560	5570	5580	5590
•	•	•	•	•	•	•
CTTTATCCGC	CTCCATCCAG	TCTATTAAAT	GTTGCCGGGA	AGCTAGAGTA	ACTAGTTGGC	CAGTTAATAG
GAAATAGGCG	GAGGTAGGTC	AGATAATTAA	CAAACGGCCCT	TCGATCTCAT	TCATCAAGCG	GTCAATTATC

>Hae2	>Ase1	>Fsp1	>Fdi2	>Hst1	>Pst1	5600	5610	5620	5630	5640	5650	5660
•	•	•	•	•	•	•	•	•	•	•	•	•
						TTTCCGCAAC	GTTGTTGCCA	TTGCTGCAGG	CATCGTCGGT	TCAACCTCGT	CGTTTCGTAT	GGCTTCATTC
						AAACGGCTTC	CAACAACCGT	AACCAAGTCC	GTAGCACCAC	AGTGGGAGCA	GCAAACCATTA	CGAAGTAAG

5670	5680	5690	5700	5710	5720	5730
•	•	•	•	•	•	•
AGCTCCGGTT	CCCAACGATC	AAGGCGAGTT	ACATCATCCC	CCATGTTGTG	CAAAAAAGCG	GTTAGCTCCT
TCGAGGCCAA	GGGTTCCTAG	TTCCGCTCAA	TGTACTAGGG	GGTACAACAC	GTTTTTTCGC	CAATCGAGGA

>Pvu1	>Eae1	>Xor2	>Cfr1	5740	5750	5760	5770	5780	5790	5800
•	•	•	•	•	•	•	•	•	•	•
				TCGGTCCCTCC	CATCGTTGTC	AGAAGTAAGT	TGGCCGCAGT	GTTATCACTC	ATCGTTATCG	CAGCACTCCA
				AGCCAGGAGG	CTAGCAACAG	TCTTCATTCA	ACCGGGGTCA	CAATAGTGAG	TACCAATACC	GTCGTGACGT

>Rsa1	>Sca1	>Hph1	5810	5820	5830	5840	5850	5860	5870
•	•	•	•	•	•	•	•	•	•
			TAATTCTCTT	ACTGTCATGC	CATCCGTAAAG	ATGCTTTTCT	GTGACTGGTG	AGTACTCAAC	CAAGTCAATC
			ATTAAGAGAA	TGACAGTAAG	GTAGGCATTC	TACGAAAGA	CATGACCAC	TCATCAGTTG	GTTCACTAAG



Table 6 (Cont'd)

GAATACTCAT ACTGTTCCCTT TTTCAATATT ATTGAAGCAT TTATCAGCGT TATTGTCTCA TGAGCGGATA
CTTATGAGTA TGACAAGCAA AAAGTTATAA TAACTTCGTA AATAGTCCCA ATAACAGAGT ACTGGCCTAT

6230 6240 6250 6260 6270 6280 6290
CATATTTCAA TGTATTTAGA AAAATAAACA AATAGGGGTT CCGCGCACAT TTCCCCGAAA AGTCCACCT
GTATAAACTT ACATAAATCT TTTTATTTGT TTATCCCCAA GCGCGGTGTA AAGCGGCTTT TCACCGTGGA

>Aat2
^
>Aha2
^
>Acy1
^
>Hae2
^
6300 6310 6320 6330 6340 6350 6360
^ ^ ^ ^ ^ ^ ^
>BspH1
^
>Pss1
^
>EcoO109I
^
>Dra2
^
GACGTCTAAG AAACCAATTAT TATCATGACA TTAACCTATA AAAATAGGCG TATCAGGAGG CCCTTTGCTC
CTGCAGATTC TTTCGTAATA ATAGTACTGT AATTGGATAT TTTTATCOGC ATAGTGCTCC GCGAAAGCAO

TTCAA
AAGTT

zymes which do not cut LXSRIIL2 :

4 3	Bgl2	Cla1	Hpa1	Hru1	SnaB1
^pa1	Bsm1	Dra3	Hlu1	PflM1	Spl1
^su2	BspK2	Eco47III	Hro1	Sac2	Sst2
^an3	BstB1	Bsp1	Not1	Sall	

To generate the LXSNI-RI-IL2 retroviral vector, 10 micrograms of pLXSNI-RI-IL2 DNA was transfected into the ecotropic packaging cell line PE501 by standard calcium phosphate precipitation methods (Miller et al., Mol. Cell Biol. 6:2895, 1986). The transfected PE501 cell line was grown in DMEM medium with 10% FCS. The medium was changed after 24 hours and supernatant harvested 24 hours later to infect the amphotropic packaging cell line PA317 as described (Miller et al., Mol. Cell Biol. 6:2895, 1986 and Miller et al., BioTechniques 7:980, 1989). The infected PA317 cells were harvested by trypsinization 24 hours later and replated 1:20 in DMEM containing 10% FCS and the neomycin analogue G418 (400 µg/ml). The cells were grown at 37°C in 7% CO₂ atmosphere. The selection medium was changed every 5 days until colonies appeared. On day 14, twenty colonies were selected, expanded and tested for viral production by standard methods (Xu et al., Virology 171:331-341, 1989). Briefly, supernatants were harvested from confluent culture dishes, passed through a .45 µm filter, diluted with DMEM with 10% FCS and utilized to infect NIH 3T3 cells in the presence of 8 µg/ml polybrene. After 24 hours, the infected NIH 3T3 cells were grown in culture medium that contained the neomycin analogue G418. After 12-14 days, the colonies were stained, counted and the viral titer calculated as described (Xu et al., Virology 171:331-341, 1989).

Colonies with the highest viral titers ($>10^4$ infectious units/ml) were tested for IL-2 expression by Northern blot analyses. Colonies with the highest viral titers and documented IL-2 expression were cryopreserved and will be utilized as stock cultures to produce the LXSNI-RI-IL2 retroviral vector trial.

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EXAMPLE IVRETROVIRAL VECTOR CONSTRUCTION AND CYTOKINE EXPRESSION

To increase IL-2 production by transduced cell lines, vectors were used containing different promoters to drive IL-2 expression, and a human IL-2 cDNA was directionally sub-cloned into the insulin secretory signal peptide (17). The IL-2 cDNA was directionally sub-cloned into the parental plasmids of the LXS_N (LTR promoter) and LNCX (CMV promoter) vectors (gifts of Dr. A.D. Miller) (18). The newly constructed vectors (Figure 1), designated as LXS_N-IL2 and LNCX-IL2, were packaged in the PA317 cell line for production of retroviral supernatant. As a control, the high level expressing, double copy vector DC/TKIL-2 vector (thymidine kinase promoter) (a gift of Dr. E. Gilboa) was used for comparison.

These vectors were used to transduce a number of murine and human, primary and established cell lines. Pools of transduced cells were selected and expanded in DMEM medium, containing 10% fetal bovine serum (FBS) and 400 µg/ml of active G-418, a neomycin analogue. The results of expression studies in the MCR9 and Balb/c 3T3 cell lines are presented in Table 7.

Table 7

Comparison of IL-2 expression by fibroblasts transduced with different IL-2 vectors.			
5	Fibroblast	Vector	Units IL-2 per 10 ⁶ cells per day
10	Murine	LNCX (Control)	0.4 ±50%
		LNCX-IL2	33.7 ±11%
		LXSN-IL2	6.6 ± 6%
		DC/TKIL-2	1.9 ± 5%
15	Human	LXSN (Control)	0.7 ±29%
		LNCX-IL2	159.5 ±17%
		LXSN-IL2	25.5 ±15%
		DC/TKIL-2	3.0 ±10%

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EXAMPLE VFIBROBLAST CULTURE AND CONDITIONS FOR RETROVIRAL
TRANSDUCTION

The culture conditions for the growth of primary
5 fibroblasts retroviral transduction were optimized.
Primary fibroblasts were successfully cultured. The
optimal conditions enable the growth of approximately 3-4
x 10⁶ primary fibroblasts from a 12 mm² skin biopsy in
approximately 4-6 weeks. Retroviral infection, G418
10 selection, and expansion of the genetically modified
fibroblasts takes an additional 4-6 weeks.

Exploring the conditions for genetic modification
of primary fibroblasts suggests that optimal transduction
may be obtained by the following procedure: The fibroblasts
15 are synchronized in G1 phase by serum starvation, followed
by stimulation with medium containing 15% fetal bovine
serum 15 hours prior to transduction. The cells are then
subjected to 2 cycles of retrovirus infection, each cycle
lasting approximately 3 hours. The cells are refed with
20 fresh media overnight, and then selection in G418 is
initiated the next day. This method is capable of
transducing 5-15% of the fibroblasts in a culture,
depending on the multiplicity of infection.

This procedure was used to transduce a large
25 number of primary and established fibroblasts. As an
example, Table 8 compares the expression levels of IL-2 in
fibroblast lines transduced with LXS-N-IL2.

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Table 8

Expression of IL-2 by fibroblasts transduced with LXS_N-IL2.

5	Fibroblast Line	Species	Origin	<u>ng IL-2 Units IL-2</u>	
				per 10 ⁶ cells	per day
	Balb/c 3T3	Murine	Transformed	6.6 ± 6%	13
	MCR9	Human	Embryonic	25.5 ± 15%	51
10	NHDF 313	Human	Skin	25.0 ± 10%	50
	GT1	Human	Skin	15.0 ± 5%	30

These results indicate that the IL-2 expression levels in established, embryonic, and primary fibroblast cultures are similar. Comparison of these data with Table 7 suggest that IL-2 expression is affected more by factors such as different promoters than by the fibroblast line used. Similarly, changes in culture conditions can have important effects on IL-2 expression. Table 9 shows that transduced GT1 cells, a primary human fibroblast culture expressed 15-fold more IL-2 under 100 µg/ml G418 selection than under 25 µg/ml G418 selection. Several other primary fibroblast lines have also been transduced with our vectors and are currently growing under G418 selection.

Table 9

Effect of G418 concentration on IL-2 expression by GT1 cells transduced with LXSN-IL2.	
Selection dose of G418	ng IL-2 secreted per 10 ⁶ cells per day*
25 µg/ml	1.0 ± 10%
50 µg/ml	3.0 ± 6%
100 µg/ml	15.0 ± 5%

*After three weeks of G418 selection.

EXAMPLE VI

15 COMPARISON OF IL-2 EXPRESSION LEVELS INDUCED PERIPHERAL BLOOD LYMPHOCYTES AND GENETICALLY MODIFIED FIBROBLASTS

In order to compare the production of IL-2 by genetically modified fibroblasts to that achieved by stimulating normal human peripheral blood lymphocytes (nPBL) in vitro, nPBL were isolated by Ficol-Paque density centrifugation, and cultured in the presence of allogeneic nPBL (mixed lymphocyte culture, MLC) or 2 µM calcium ionophore (CI) (A23187) free acid) plus 17 nM phorbol 12-myristate 13-acetate (PMA). The results of this experiment, present in Table 10, indicate that the level of IL-2 expression in the PMA/CI stimulated normal T cell population was 2 ng/10⁶ cells/24 hours. This is equivalent to IL-2 expression by Balb/c 3T3 fibroblasts transduced with DC/TKIL-2 (Table 7), our least productive vector. The level of IL-2 expression in the MLC was 130 pg/10⁶ cells/24 hours. This was lower than the PMA/CI stimulated culture, presumably because PMA/CI induced a nonspecific response

while MLC resulted in specific Th stimulation. When the estimated percentage of antigen-specific Th in the MLC-stimulated population is taken into consideration, the level of IL-2 expression per stimulated T cell becomes equivalent for both methods.

Table 10
Levels of IL-2 secretion by different cells.

10	Cells	pg IL-2 secreted per 10 ⁶ cells per day
Lymphocytes:		
	Control (non-activated)	5 ± 50%
	PMA + Calcium Ionophore	2,000 ± 6%
15	Mixed lymphocyte culture	130 ± 90%
Transduced fibroblasts:		
	MCR9-LXSN-IL2	24,000 ± 5%
	MCR9-LNCX-IL2	162,000 ± 20%
	MCR9-DC/TKIL-2	10,000 ± 6%
20		

EXAMPLE VII

FIBROBLAST MEDIATED CYTOKINE GENE THERAPY IN MURINE TUMOR MODELS

Two experimental protocols were used to study the efficacy of fibroblast-mediated cytokine gene therapy on induction of anti-tumor immunity. The first protocol was designed to test the effects of genetically modified fibroblasts on tumor implantation, while the second protocol was designed to induce a systemic anti-tumor immunity. The results of each experiment are presented with two figures and one table. In the first figure, the rate of tumor growth for each treatment group is presented

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as the mean tumor size in the group over time. In the second figure, a Kaplan-Meier curve presents the time of tumor onset for the individual animals in each treatment group. The number of animals, the number and percentage of tumor free animals, and the tumor size distribution patterns for each experiment are presented in a table.

EXAMPLE VII(a)

EFFECT OF FIBROBLAST MEDIATED CYTOKINE GENE
THERAPY ON TUMOR IMPLANTATION

10 Mice were injected subcutaneously with mixtures
of 5×10^4 CT26 cells and 2×10^6 fibroblasts genetically
modified by different retroviral vectors to express IL-2.
In the control arms injected with tumor cells only, or with
tumor cells mixed with unmodified fibroblasts, 31 of 33
15 animals (94%) developed tumors by 4 weeks (Figures 6 and 7,
Table 9). In contrast, 22 out of the 34 animals (65%)
receiving fibroblast mediated cytokine gene therapy were
tumor free at 3 weeks, and 5 animals (18%) remain tumor
free after 12 weeks. Those animals that received
20 fibroblast mediated IL-2 therapy and developed tumor were
characterized by a delayed onset and rate of tumor growth.

After 3 weeks the mean tumor size (measured as the product of the longest and widest tumor axes) in the control group of mice was 128 mm², compared to 68 and 7 mm² in groups of mice injected with tumor cells mixed with
5 fibroblasts transduced with DC/TKIL-2 or LNCX-IL2, respectively. This resulted in a highly significant difference (corrected $\chi^2 = 18.69$, $p = 0.001$) between the IL-2 treated animals compared to the mice treated with CT26 alone or CT26 mixed with unmodified fibroblasts. After
10 four weeks the equivalent measurements were 373, 300 and 72 mm² (Table 11). It is notable that LNCX-IL2, the highest expressing vector caused substantially greater inhibition of tumorigenicity than the lower expressing vector DC/TKIL-2. A multivariate non-parametric statistical procedure
15 (19,20), utilized to evaluate differences in tumor growth, demonstrated that after 4 weeks the differences between the growth curves for the four groups presented in Figure 2 were highly significant ($p < 0.001$). Subsequent comparisons between the control arm and animals that
20 received tumor cells mixed with IL-2 transduced fibroblasts revealed a significant difference ($P < 0.05$). The differences between the animals injected with tumor cells alone, and those injected with tumor cells plus unmodified fibroblasts were not significant, while the differences
25 between animals receiving low IL-2 expressing fibroblast, and those receiving high IL-2 expressing fibroblasts was significant ($P = 0.05$).

When mice were injected with 2×10^6 modified fibroblasts mixed with 1×10^5 live tumor cells the results
30 became more striking (see Figures 8 and 9, and Table 12). All the control animals developed tumors after 4 weeks whereas 33% and 27% of the animals treated with fibroblasts modified with the DCTK-IL2 or LXSX-IL2 vectors (respectively) remain tumor free after 7 weeks (the
35 experiment is ongoing). More dramatically, 75% of the animals treated with fibroblasts modified with the highest

IL-2 producing vector, LNCX-IL2, remain tumor free after 7 weeks. These data clearly demonstrate the importance of an initial high dose of IL-2 to prevent tumor establishment.

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Table 12

Effect of IL-2 modified fibroblasts on tumor establishment and development.
2 X 10⁶ fibroblasts mixed with 1 X 10⁵ CT26 tumor cells at time of injection.

Fibroblasts mixed with tumor cells	Animal Number		Percent Tumor-free	Tumor Size (mm ²)				Mean Tumor Size (mm ²)
	Total	Tumor- free		25-100	101-200	201-300	>301	
After 6 Weeks:								
Control (no fibroblasts)**	13	0	13	0	5	2	5	315 ± 197
Unmodified fibroblasts**	20	0	20	0	2	3	14	350 ± 100
DCTK-IL2 fibroblasts	12	4	8	0	1	4	3	185 ± 141
LXSN-IL2 fibroblasts***	15	4	11	0	5	1	2	135 ± 121
LNCX-IL2 fibroblasts	8	6	2	2	0	0	0	8 ± 14

* Mean tumor size is for 4 weeks, the last timepoint at which tumors were measured.

** One mouse in each of these arms developed an intraperitoneal tumor which was not measurable.

*** Three mice in this arm developed intraperitoneal tumors which were not measurable.

As an additional control, mice were injected with CT26 cells genetically modified to express IL-2 (results not shown). Injection of up to 1×10^6 IL-2 expressing tumor cells into Balb/c mice failed to produce tumors.

5 Injection of higher numbers however, resulted in some animals developing tumors with delayed onset. These data confirm the results reported in the literature (1). In order to compare the efficacy of IL-2 producing fibroblasts to IL-2 producing tumor cells, we mixed 2×10^6 CT26 tumor

10 cells modified with the DCTK-IL2 vector with 1×10^5 unmodified tumor cells. Figures 10 and 11, and Table 13 show that DCTK-IL2 modified tumor cells are somewhat effective in preventing tumor development. Four weeks after injection, the mean tumor size for the treatment arm

15 is 303 mm^2 , compared to 620 mm^2 for the control arm. After 22 weeks, one animal (10%) remains tumor free, compared to none in the control arms. Data for animals treated under the same conditions with DCTK-IL2 modified fibroblasts in a separate experiment are included for comparison purposes.

20 This comparison suggests that DCTK-IL2 modified tumor cells have an effect on tumor establishment similar to that of DCTK-IL2 modified fibroblasts.

EXAMPLE VII(b)EFFECT OF FIBROBLAST MEDIATE CYTOKINE GENE THERAPY
ON SYSTEMIC ANTI-TUMOR IMMUNITY

Groups of Balb/c mice were immunized with
5 2.5×10^5 irradiated tumor cells either alone or mixed with
 2×10^6 transduced or unmodified fibroblasts, and challenged
one week later with 5×10^4 live tumor cells in the opposite
flank. These results (Figures 12 and 13, and Table 14)
demonstrate that immunization with irradiated tumor cells
10 and transduced fibroblasts protect some animals against a
live tumor challenge, but that the protection is only
slightly better than that achieved by immunization with
irradiated tumor cells alone or irradiated tumor cells
mixed with unmodified fibroblasts.

In a second protocol similar to the one described above, animals were challenged with fresh tumor cells two weeks following immunization with irradiated tumor cells mixed with fibroblasts. The results, shown in Figures 14 and 15, and in Table 15, demonstrate that DCTK-IL2 modified fibroblasts mixed with irradiated tumor cells confers superior protection to subsequent tumor challenge than irradiated tumor cells alone, irradiated tumor cells mixed with unmodified fibroblasts, or irradiated tumor cells mixed with LNCX-modified fibroblasts. After 7 weeks, seven of ten animals (70%) treated with DCTK-IL2 modified fibroblasts remain tumor free compared to only one third of the control animals. At four weeks, the mean tumor size of this group was 41 mm², compared to 180, 170, and 140 mm² for the three control groups. Animals treated with LNCX-IL2 modified fibroblasts were also protected against subsequent tumor challenge, but the results were less striking. In this group, 54% of the animals remain tumor free and the mean tumor size for the group at four weeks was 86 mm². The number of tumor free animals in the group treated with LXSN-IL2 modified fibroblasts was similar to the control groups, although the tumors were slightly delayed in their onset. A multivariate non-parametric statistical procedure (19, 20), utilized to evaluate differences in tumor onset, demonstrated that the differences for the six arms presented in Figure 15 were significant ($p = 0.012$). It further showed that the saline control arm and the arms that received irradiated tumor cells alone or mixed with unmodified or LNCX vector modified fibroblasts formed a statistical group. A second, distinct statistical group was formed by the three arms that received IL-2 vector modified fibroblasts mixed with irradiated tumor cells. Subsequent comparisons between the saline injected control arm and animals that received tumor cells mixed with IL2 transduced fibroblasts revealed a significant difference for all vectors ($p < 0.05$).

Table 15

Effect of IL-2 modified fibroblasts on induction of sytemic anti-tumor immunity.
Mice immunized with 2×10^6 fibroblasts mixed with 2.5×10^5 irradiated CT26 tumor cells 14 days prior to challenge with 5×10^4 fresh tumor cells.

Immunization by fibroblasts mixed with irradiated tumor cells	Animal Number			Percent Tumor-free	Tumor Size (mm ²)				Mean Tumor Size (mm ²)
	Total	Tumor- free	Tumor- bearing		25-100	101-200	201-300	>301	
After 7 Weeks:**									
Control (saline)**	8	1	7	13%	0	2	1	3	245 ± 173
Irradiated CT26 only	10	3	7	30%	0	2	4	1	180 ± 155
Irradiated CT26 mixed with unmodified fibroblasts	6	2	4	33%	0	2	1	1	170 ± 160
Irradiated CT26 mixed with LNCX-modified fibroblasts	10	3	7	30%	3	0	1	3	140 ± 142
Irradiated CT26 mixed with LNCX-IL2-modified fibroblasts	13	7	6	54%	1	3	1	1	86 ± 112
Irradiated CT26 mixed with LXSN-IL2-modified fibroblasts	12	4	8	33%	5	0	2	1	111 ± 145
Irradiated CT26 mixed with DCTK-IL2-modified fibroblasts	10	7	3	70%	1	2	0	0	41 ± 75

* Mean tumor size is for 4 weeks, the last timepoint at which tumors were measured.

** One mouse in this arm developed an intraperitoneal tumor which was not measurable.

These results demonstrate the feasibility of using genetically modified fibroblasts as a means of delivering cytokine gene therapy. In all experiments, the LNCX-L2 vector proved superior in preventing tumor establishment while the DCTK-IL2 vector was better in the induction of systemic protection against subsequent tumor challenges. These contrasting effects, although somewhat surprising, can be explained by the observation that the CMV promoter is turned off in vivo five days after implantation while the TK promoter remains active for a longer period of time. The implication of this finding is that to apply this method of gene therapy successfully we have to use promoters that result in high level, sustained expression of IL-2 in vivo in the transduced fibroblasts.

The data obtained from this research effort has important implications for all cytokines that have either direct or indirect anti-tumor effects. Furthermore, this data suggests that anti-tumor efficacy is IL-2 dose dependent. Hence, construction of vectors which result in higher levels of cytokine secretion will be a significant advance toward the application of this method of gene therapy.

Reference numbers in parenthesis in the above examples correspond to the following list of references and are incorporated herein by reference.

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SUBSTITUTE SHEET

Although the invention has been described with reference to the presently-preferred embodiment, it should be understood that various modifications can be made without departing from the spirit of the invention.

5 Accordingly, the invention is limited only by the following claims.

WE CLAIM:

1. A method of treating cancer in a patient comprising the stimulation of that patient's immune response against the cancer by immunizing said patient at a site other than an active tumor site with a formulation
5 comprising tumor antigens and CE cells genetically modified to express at least one cytokine gene product.
2. The method of claim 1 wherein tumor cells previously isolated from said patient provide the tumor antigens.
3. The method of claim 1 wherein the cytokine gene is selected from the group consisting of interleukin-1, interleukin-2, interleukin-3, interleukin-4, interleukin-5, interleukin-6, and gamma-interferon.
4. The method of claim 3 wherein one cytokine gene is interleukin-2.
5. The method of claim 1 wherein at least one cytokine gene is transferred into cells to generate CE cells by recombinant methods.
6. The method of claim 5 wherein the cytokine gene is present in an expression vector.
7. The method of claim 6 wherein said expression vector additionally contains a suicide gene.
8. The method of claim 5 wherein the CE cells are generated from fibroblasts and antigen-presenting cells.

9. A method for enhancing a patient's immune response to a cancer comprising:

- a) isolating fibroblasts from said patient;
- 5 b) culturing said fibroblasts in vitro;
- c) transducing said fibroblasts with a retroviral expression vector containing the gene coding for IL-2 and a gene coding for a tumor antigen in a
10 retroviral expression vector, to express said tumor antigen and to express and secrete said IL-2 by said fibroblasts; and
- d) immunizing said patient with said
15 fibroblasts that express IL-2 at a level sufficient to enhance an immune response but low enough to avoid substantial systemic toxicity and that express said tumor antigen, at a site
20 other than an active tumor site.

10. The method of claim 9 wherein said fibroblasts are further modified to express a suicide gene.

11. A composition for increasing a patient's immune response to tumor antigens comprising tumor antigens and CE cells genetically modified to express at least one cytokine gene product.

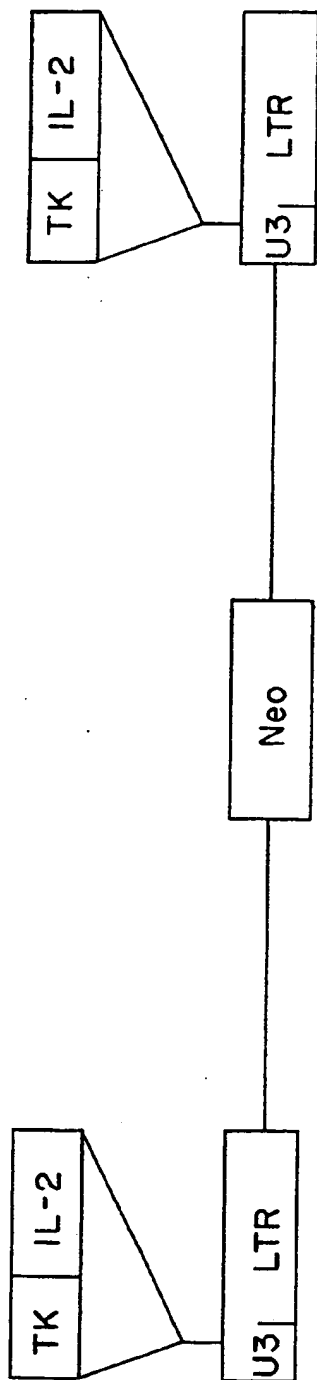
12. The composition of claim 11 wherein the cytokine gene is selected from the group consisting of interleukin-1, interleukin-2, interleukin-3, interleukin-4, interleukin-5, interleukin-6, and gamma interferon.

13. The composition of claim 12 wherein on cytokine gene is interleukin-2.

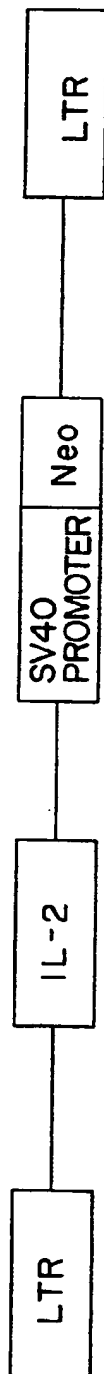
14. The composition of claim 11 wherein each cytokine gene is expressed at a level sufficient to stimulate the immune response but low enough to avoid substantial systemic toxicities.

15. The method of claim 9 wherein in said transducing step said retroviral expression vector has a promotor causing sustained secretion of IL-2.

16. The method of claim 15 wherein said retroviral expression vector causes the secretion of at least four units of IL-2 per day for a period of ten days or longer.



RETROVIRAL VECTOR DC/TKIL2



RETROVIRAL VECTOR LXSN-IL2



RETROVIRAL VECTOR LNCX-IL2

FIG. 1

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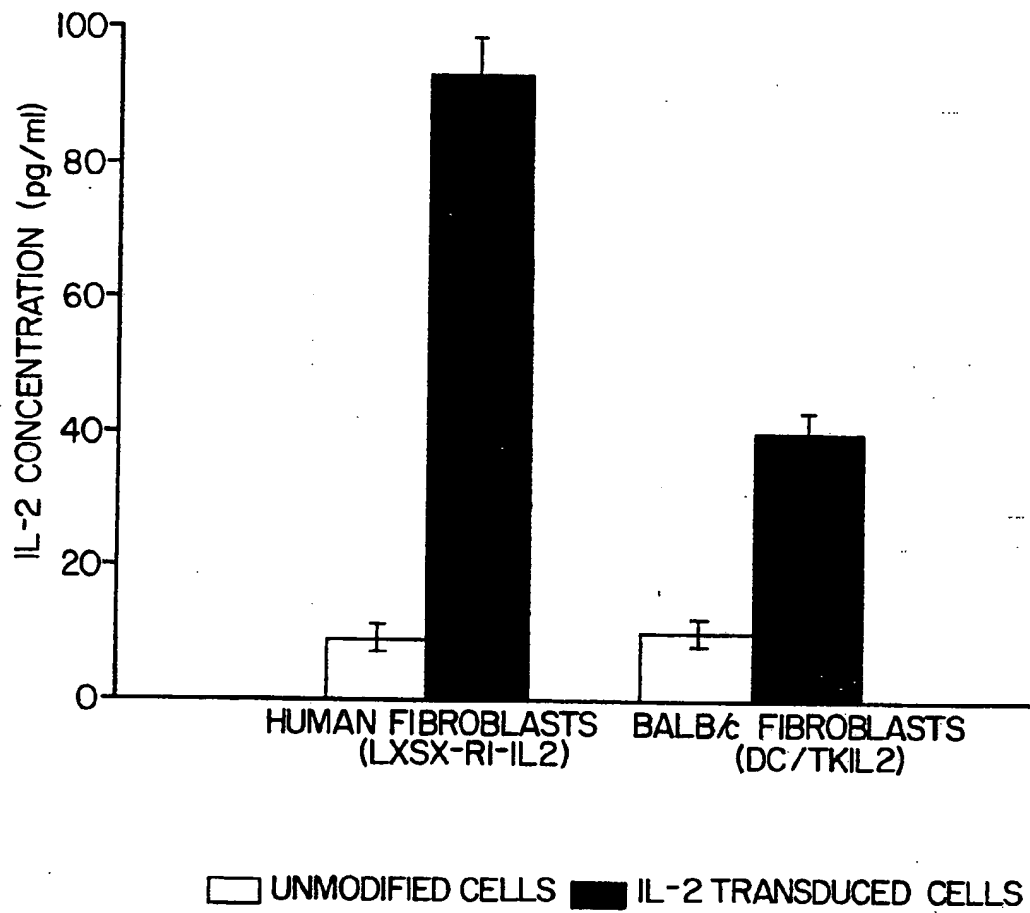


FIG. 2

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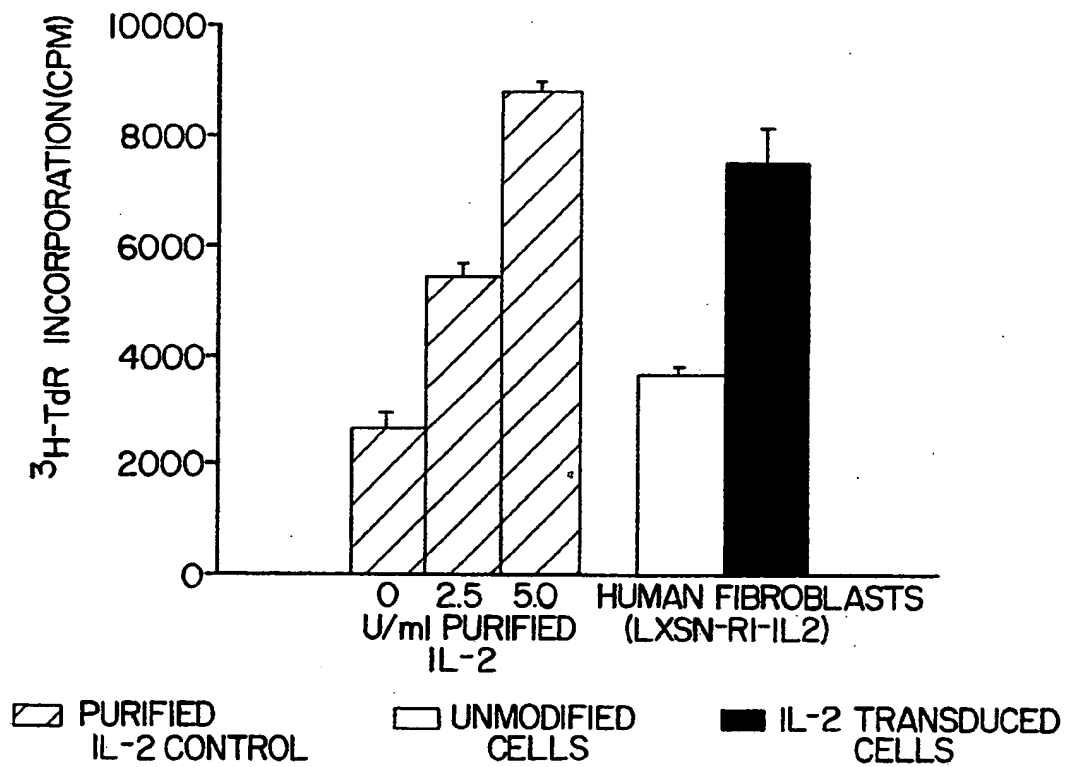


FIG. 3

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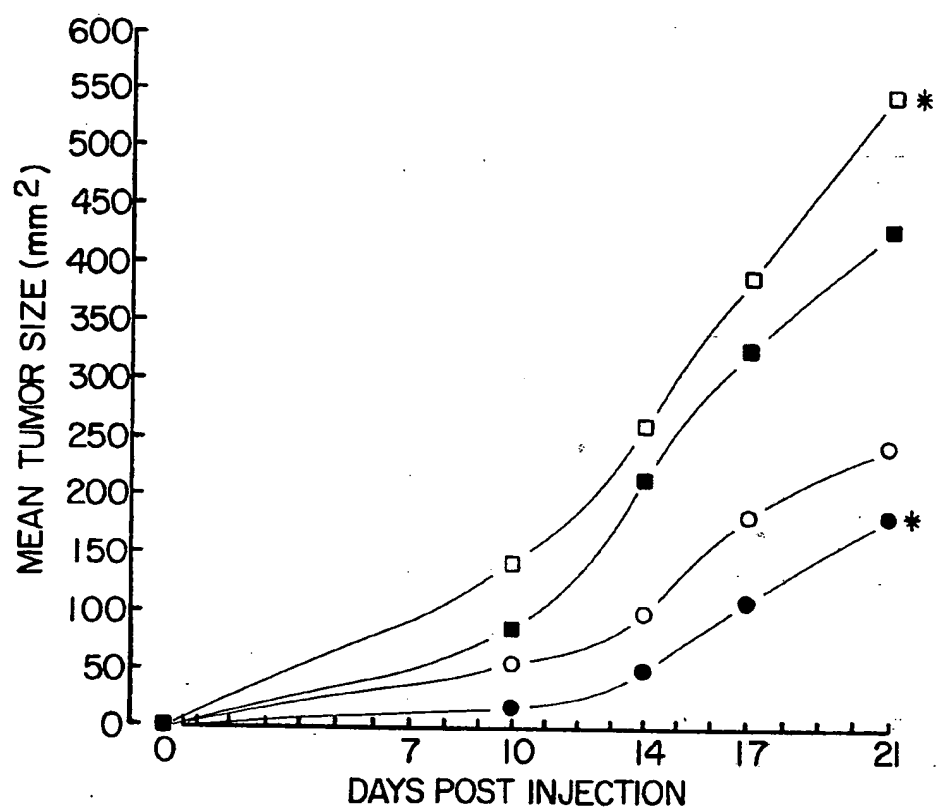
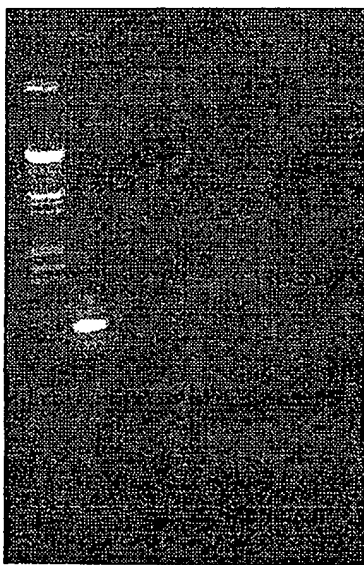


FIG. 4



1 2 3 4 5 6 7

FIG. 5

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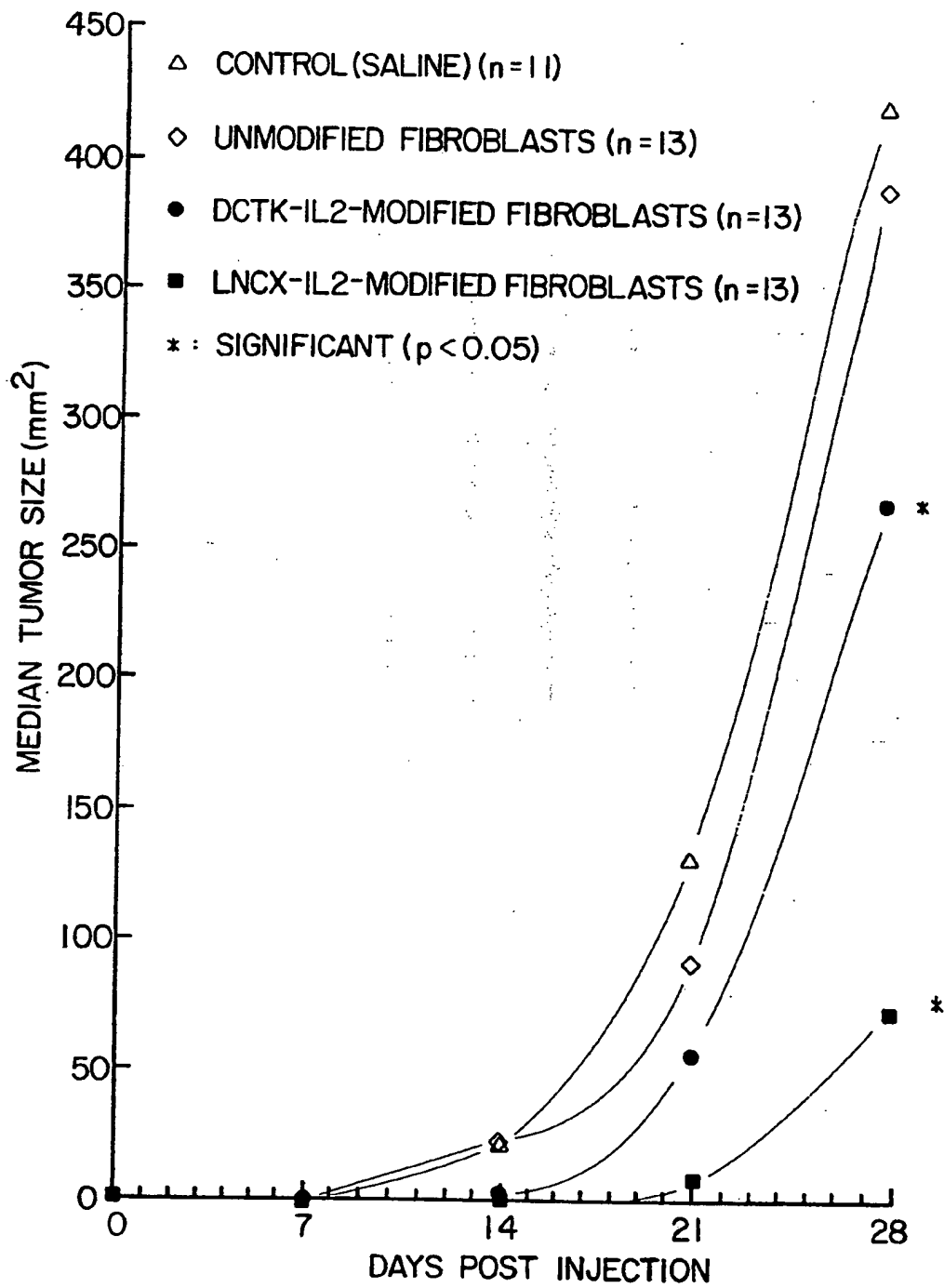


FIG. 6

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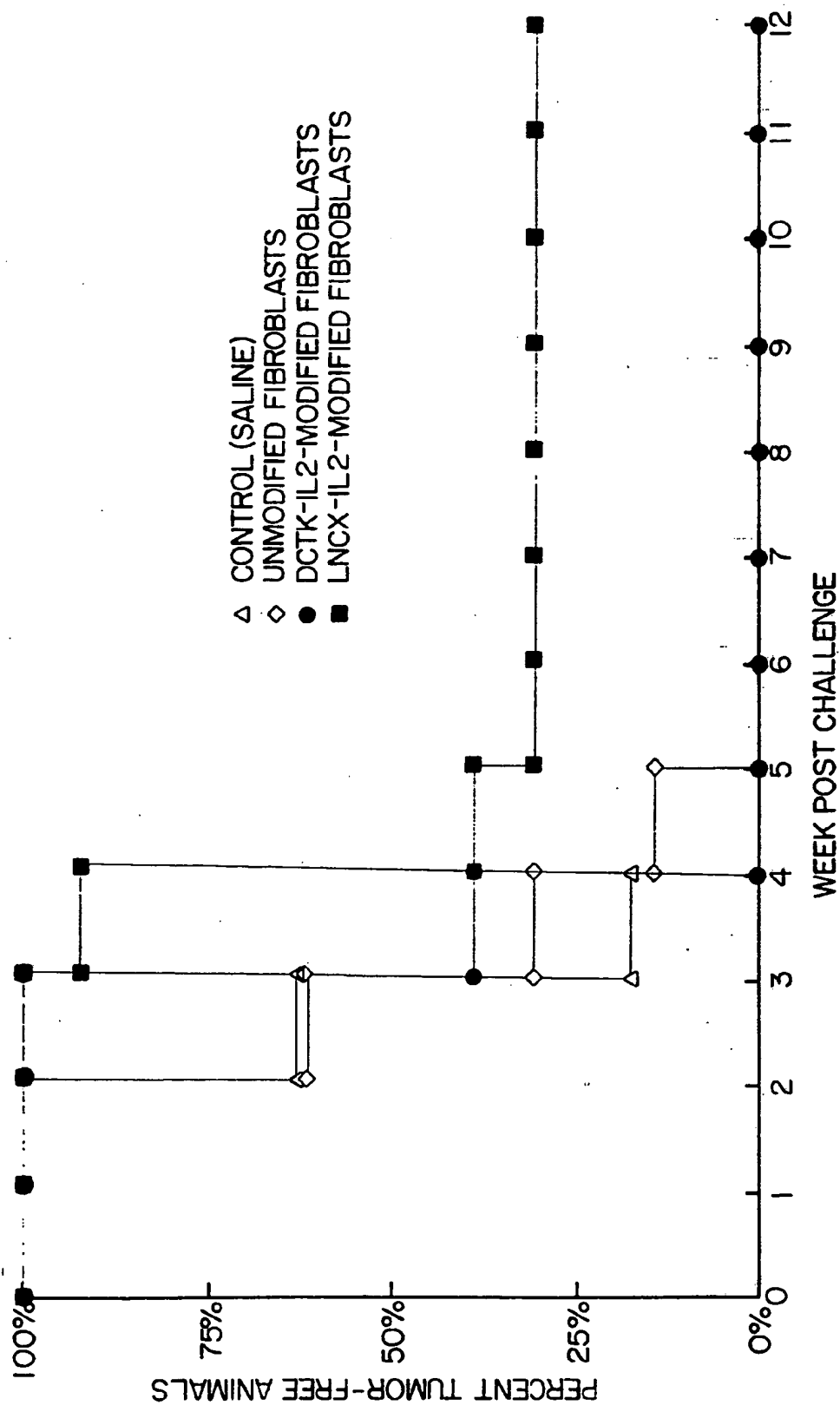


FIG. 7

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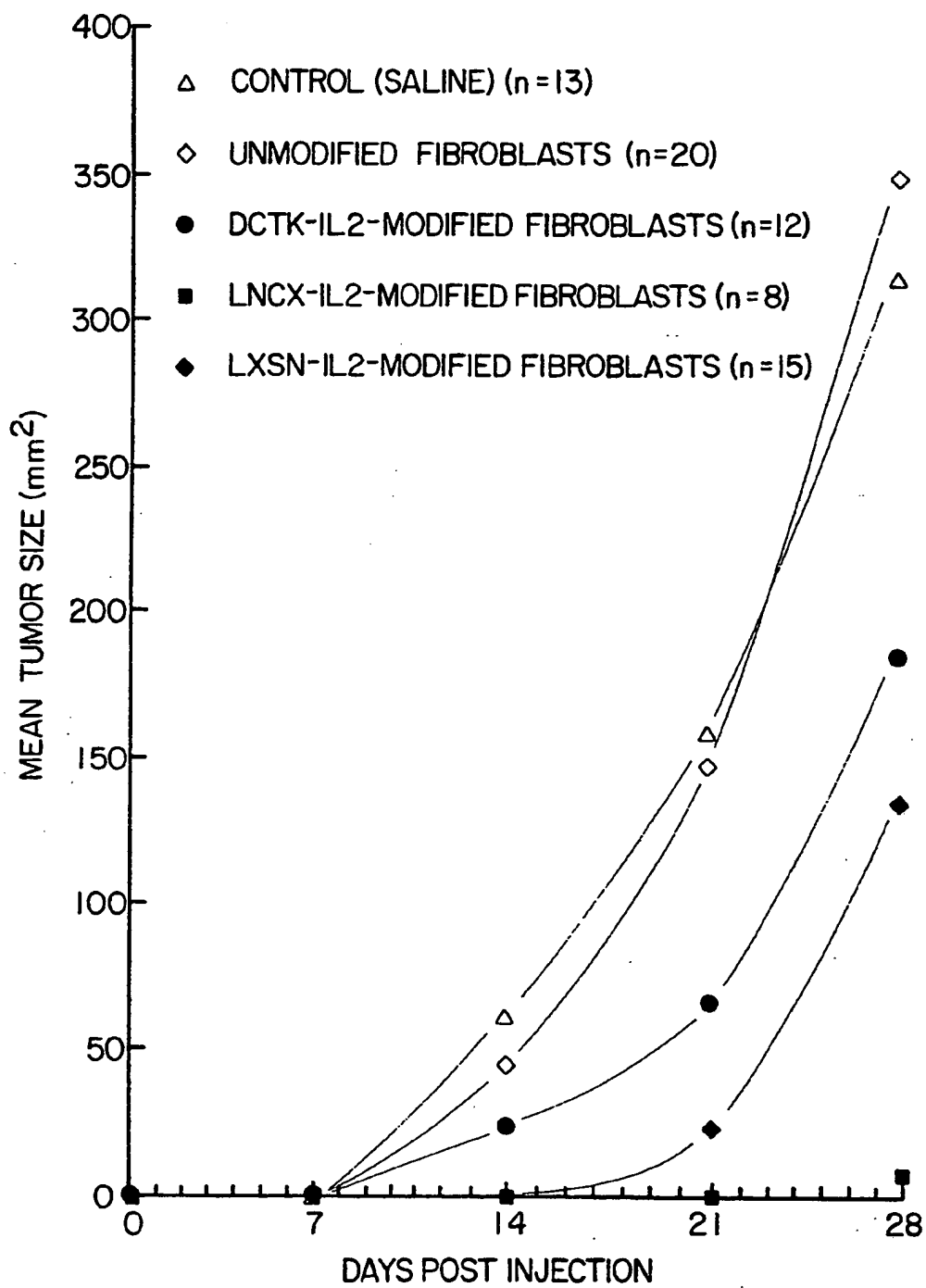


FIG. 8

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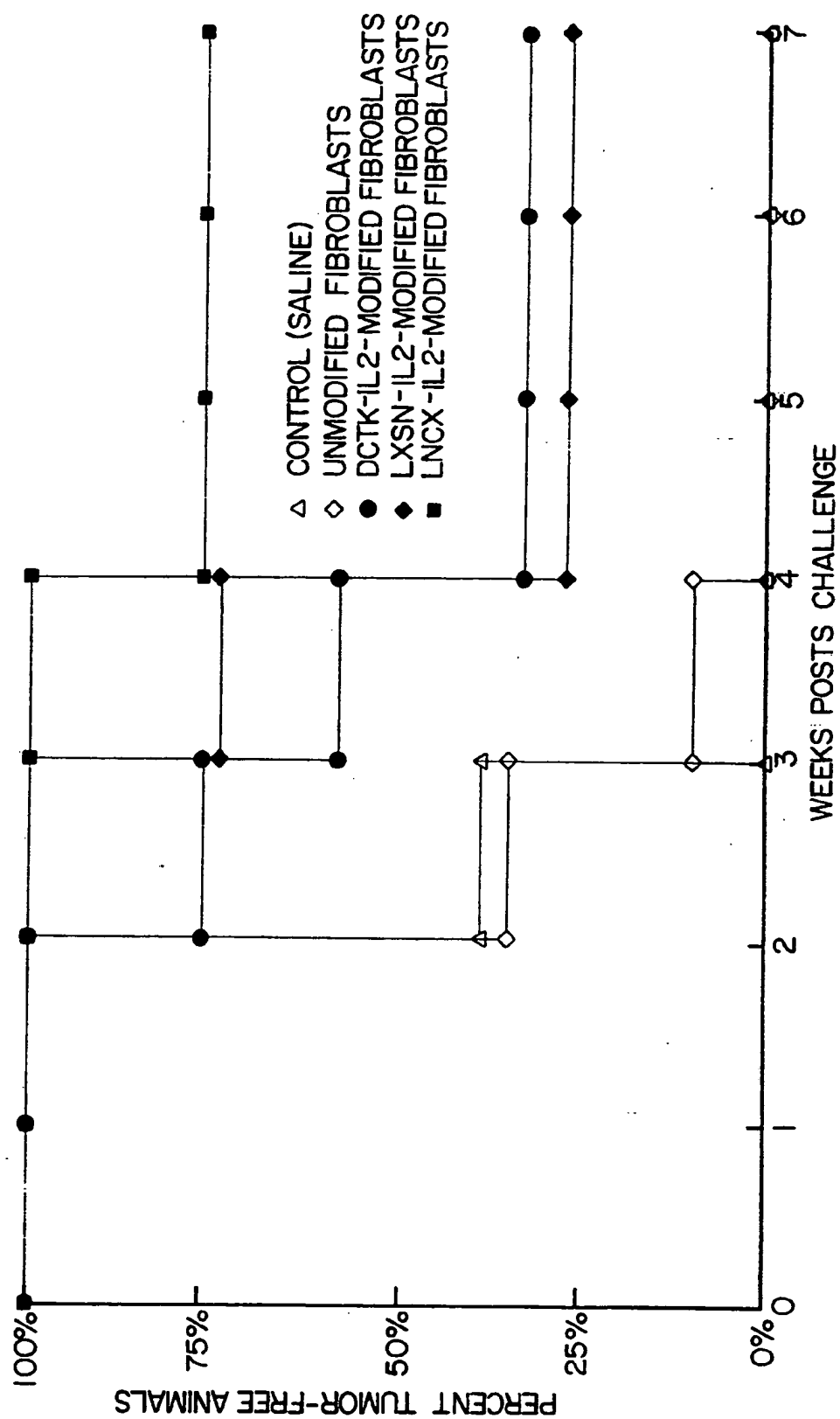


FIG. 9

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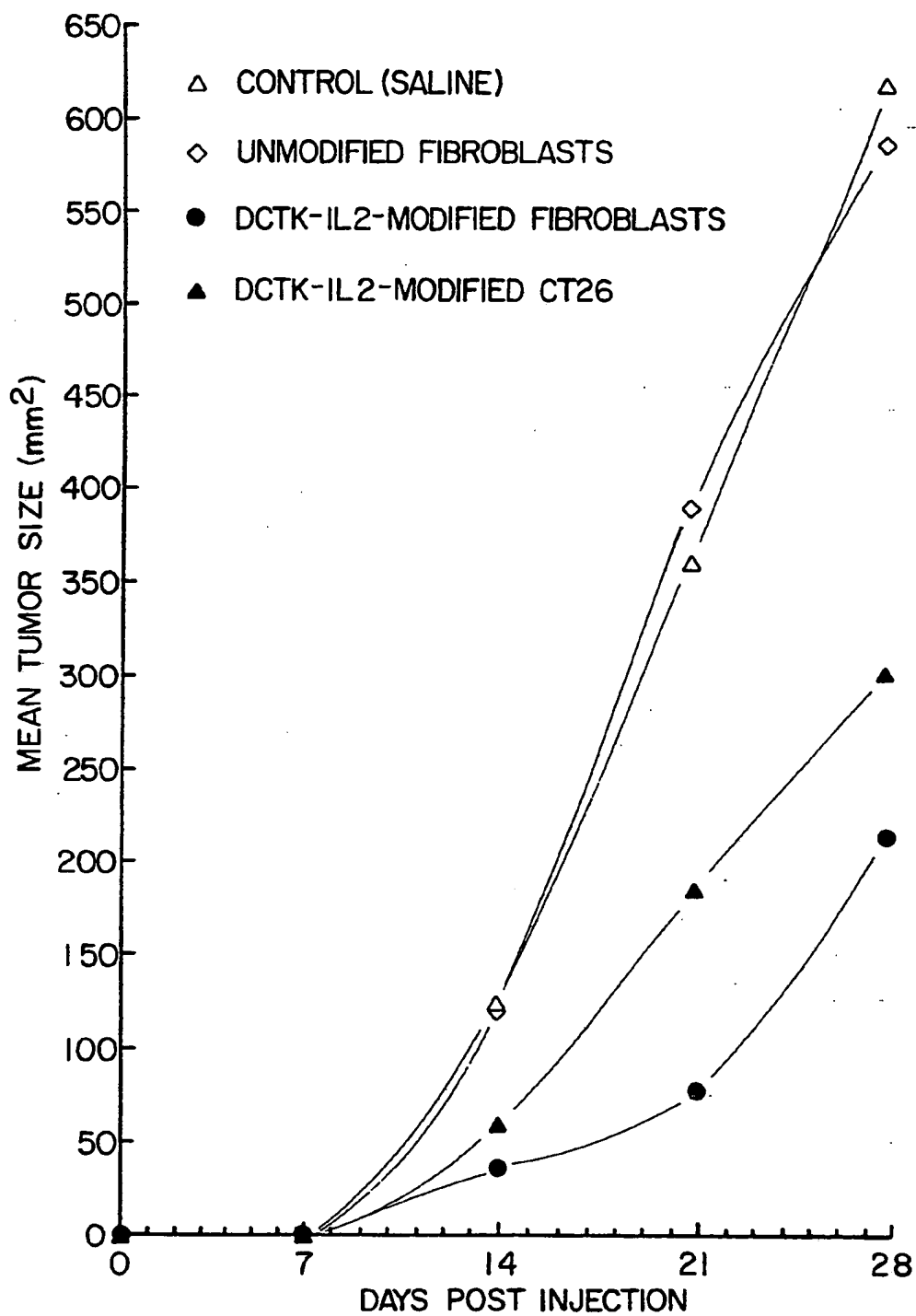


FIG. 10

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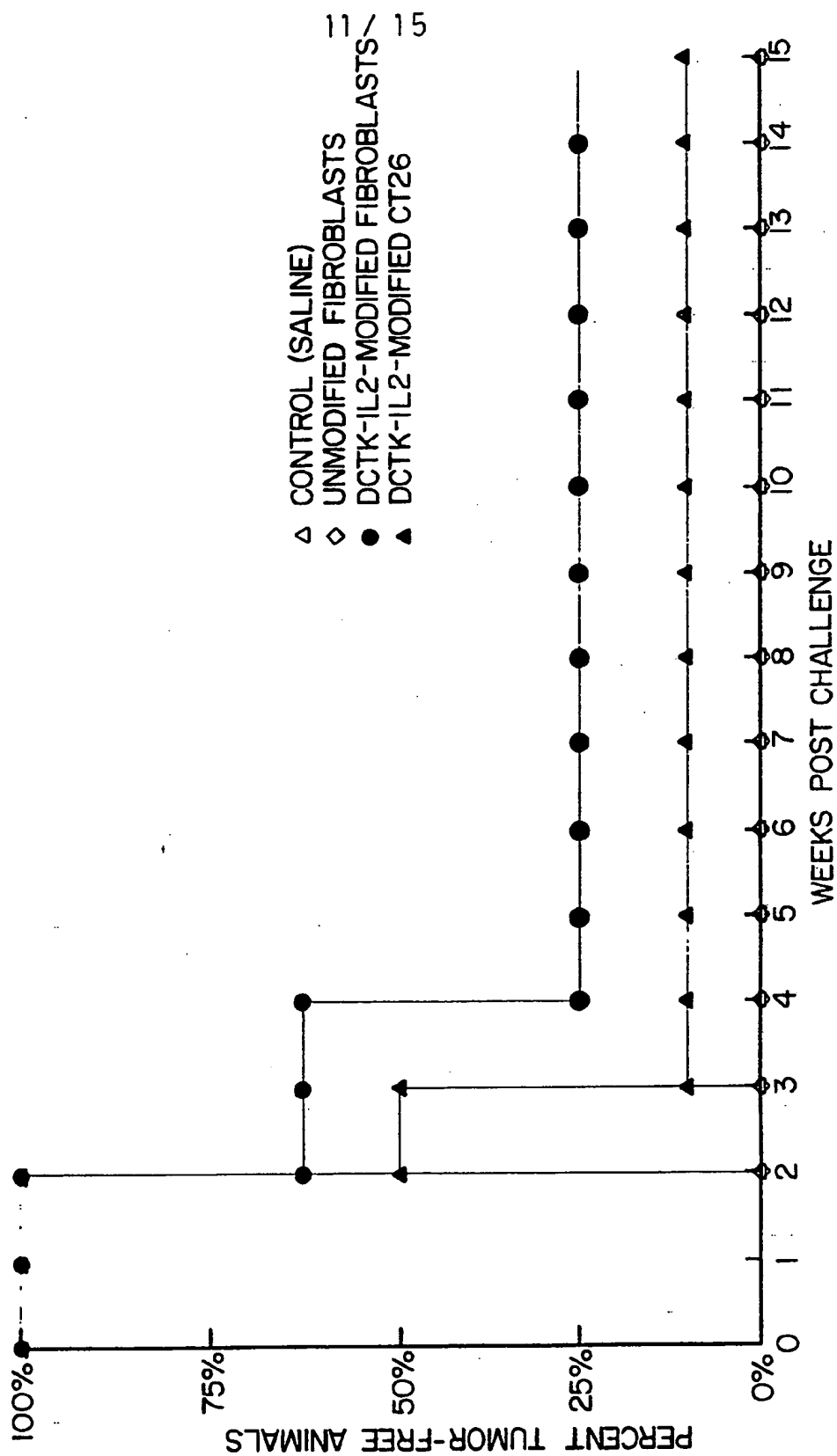


FIG. 11

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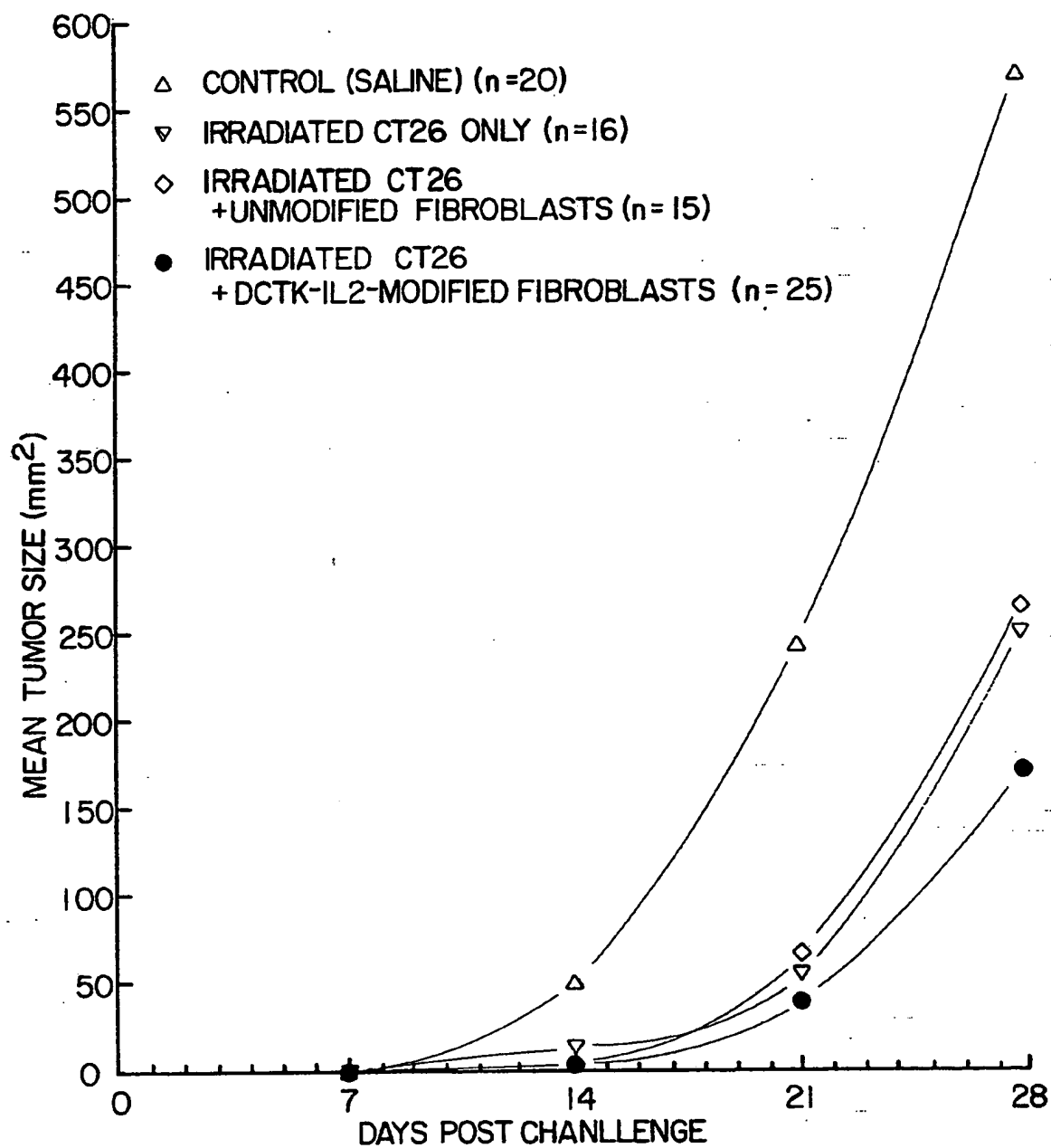


FIG. 12

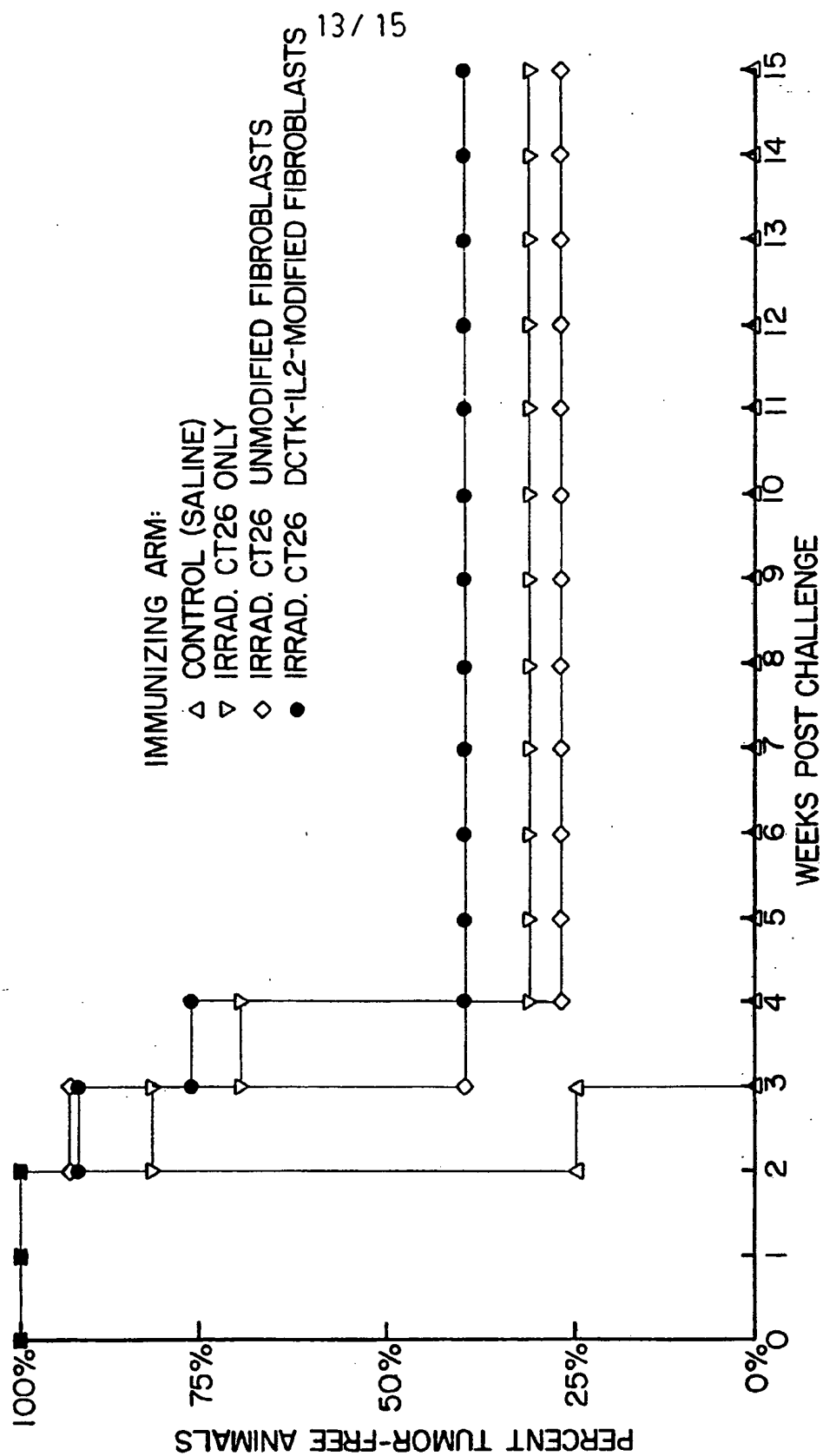


FIG. 13

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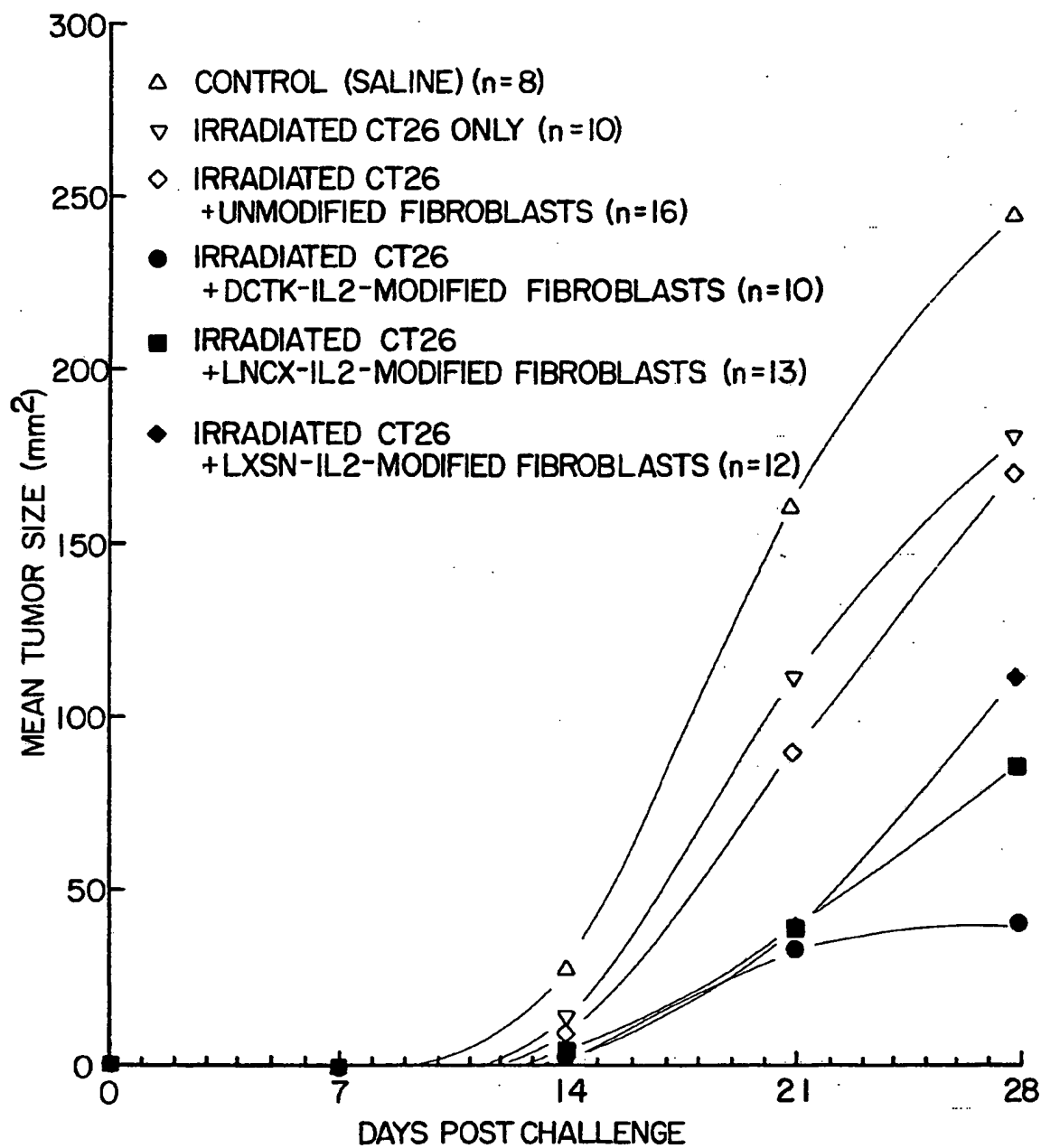


FIG. 14

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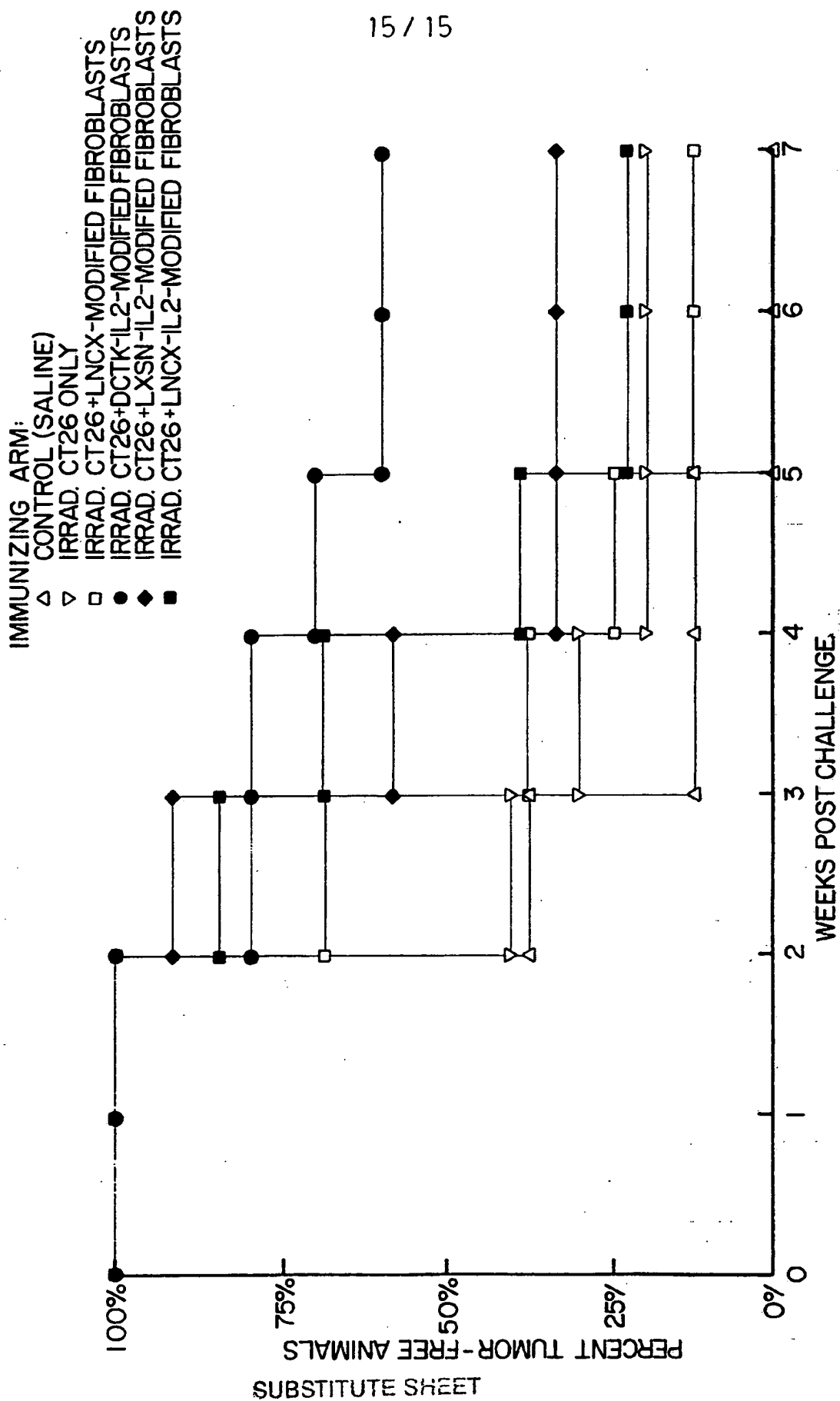


FIG. 15

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US92/08999

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) : Please See Extra Sheet.

US CL : Please See Extra Sheet.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 424/93B, 93U, 89; 435/240.2, 320.1, 69.5, 69.51, 69.52; 935/65, 32, 12, 57, 70, 71

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

BIOSIS, MEDLINE, APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	Journal of Experimental Medicine, Volume 172, issued October 1990, Gansbacher et al, "Interleukin 2 Gene Transfer into Tumor Cells Abrogates Tumorigenicity and Induces Protective Immunity", pages 1217-1224, see the entire document.	<u>1-8, 11-14</u> 9, 10, 15, 16
X Y	Cell, Volume 57, issued 05 May 1989, Tepper et al, "Murine Interleukin-4 Displays Potent Anti-Tumor Activity In Vivo", pages 503-512, see the entire document.	<u>1-3, 5, 6, 8, 11, 12, 14</u> 4, 13
X Y	Cell, Volume 60, issued 09 February 1990, Fearon et al., "Interleukin-2 Production by Tumor Cells Bypasses T Helper Function in the Generation of an Antitumor Response", pages 397-403, see the entire document.	<u>1, 3-5, 8, 11-13</u> 2, 6, 7, 14-16
Y	Cancer Research, Volume 50, issued 15 August 1990, Ogura et al., "Implantation of Genetically Manipulated Fibroblasts into Mice as Antitumor α -Interferon Therapy", pages 5102-5106, see the entire document.	1-16

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

* Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be part of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means		
"P" document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

11 January 1993

Date of mailing of the international search report

26 JAN 1993

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US92/08999

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
<input checked="" type="checkbox"/> Y	Cancer Research, Volume 50, issued 15 December 1990, Gansbacher et al., "Retroviral Vector-mediated Interferon Gene Transfer into Tumor Cells Generates Potent and Long Lasting Antitumor Immunity", pages 7820-7825, see the entire document.	<u>1, 3, 5, 6, 8, 11, 12, 14</u> 2, 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US92/08999

A. CLASSIFICATION OF SUBJECT MATTER:

IPC (5):

A61K 48/00, 35/12, 39/00; C12N 15/19, 15/24, 15/25, 15/26, 15/90, 15/63

A. CLASSIFICATION OF SUBJECT MATTER:

US CL :

424/93B, 93U, 89; 435/240.2, 320.1, 69.5, 69.51, 69.52; 935/65, 32, 12, 57, 70, 71